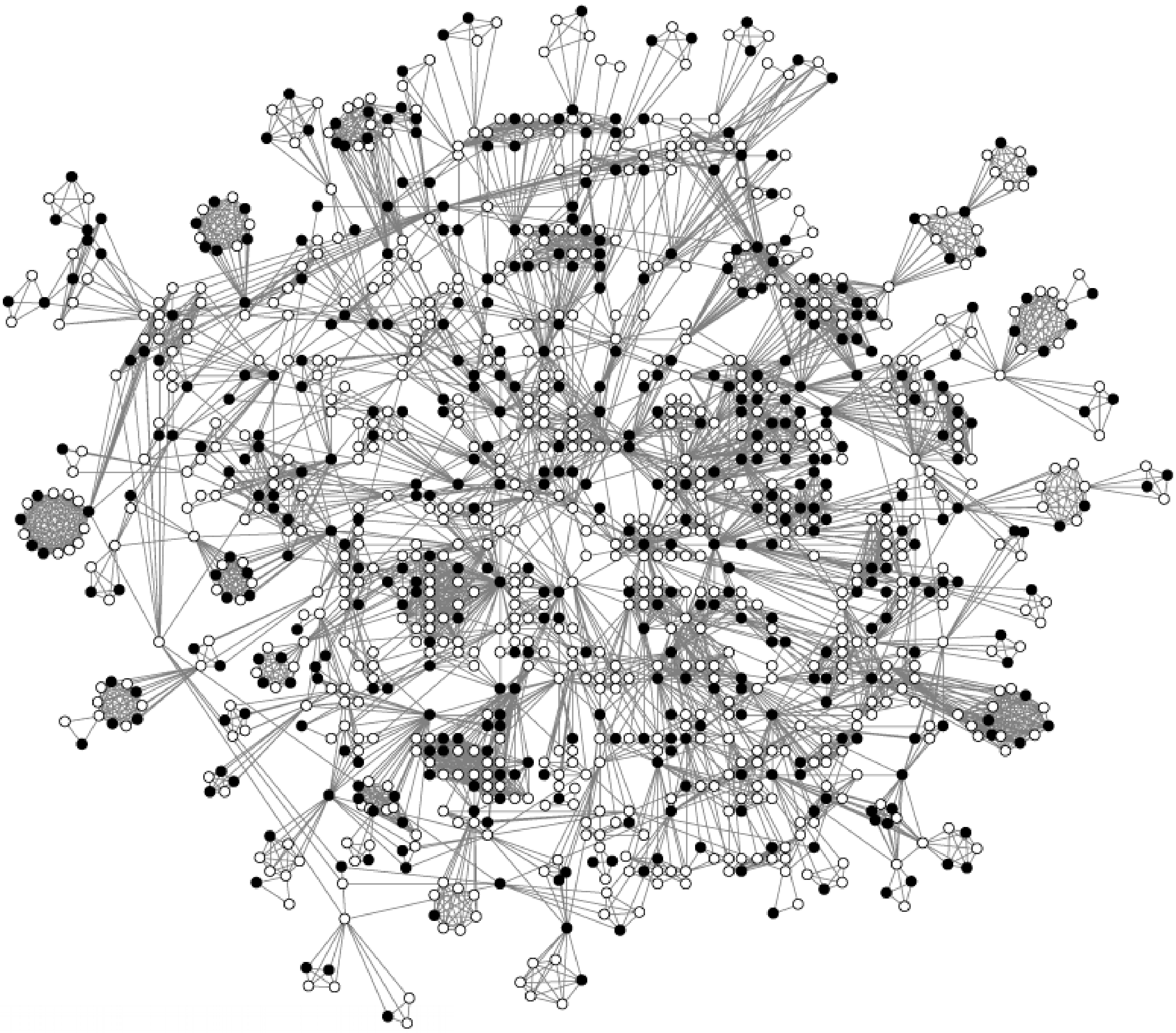
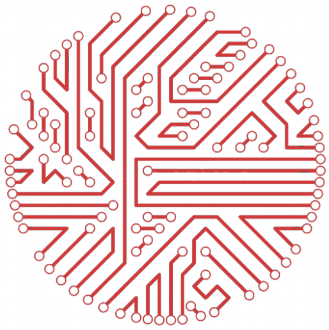
CYBERNETIKA





An introduction to the scientific study of control and communication in the animal and the machine.

Everything about systems, communications, governance models, control, and management in a simple yet reunited cybernetics modeling framework.

Recommendation: Take notes for each section and explain it to yourself, the document requires processing in order to ensure the best understanding.

Table of Contents

Prerequisite......12
- **Critical thinking**......12
  - *Foreword*......12
  - *Content Is thinking, thinking is content*......13
  - *Activated ignorance, activated knowledge*......14
    - *Inert Information*......14
    - *Activated ignorance*......15
    - *Activated knowledge*......16
  - *Bases of critical thinking*......19
  - *The intellectual standards*......20
  - *The elements of reasoning*......21
  - *Intellectual traits*......24
  - *Becoming a critic of your thinking*......26
    - *Clarify your thinking*......28
    - *Stick to the point*......29
    - *Question questions*......30
    - *Be reasonable*......31
    - *Thinking gets us into trouble because we often:*......32
    - *A how-to list for dysfunctional living*......34
- **System mindset**......36
  - *Introduction*......36
  - *Control is what you want*......37
  - *A collections of separate systems*......39
  - *The frenetic life*......41
  - *How things happen*......42
  - *99.9% of everything works just fine*......44
  - *There's not that much to fix*......45
  - *Your task is to create value*......46
  - *Begin at the bottom*......46
  - *Systemic mindset analogy*......47
  - *Automate and delegate*......47
  - *Deals killers and the main machine*......48
  - *The fabric of your life*......49

About systems......51
- **Systems philosophy**......51
  - *A mechanistic world*......51
  - *Perceived limitations*......51
  - *Life and the second law*......52
  - *Information and entropy*......53
  - *Causality and teleology*......53

- *Concept of open systems* 54
- *Summary* 54
- *Applied science* 55
- *What defines a system?* 56
- *Tenets of systems philosophy* 58
- *Understanding emergence* 58
- *Emergence and hierarchy* 59
- *Designing and creating emergence* 60
- *Conclusion* 65

Systems approach 66
- *Systems methods* 69
- *System abstraction* 70
- *Systems synthesis* 71

System models 75
- *Fundamentals* 75
- *First system model* 75
- *System definition and ideas* 76
- *The first system principle and corollary* 77
- *Nature of systems models* 77
- *Second system model* 78
- *Self-similarity, nesting, recursion and hiding* 79
- *Generic reference model* 80
    - *Generic reference: (Function) model* 80
    - *Generic reference: (Form) model* 83
    - *Generic reference: (Behaviour) model* 84
- *The GRM in action* 85

System engineering 91

Philosophy of systems engineering 91
- *Abstract* 91
- *Introduction* 92
- *Levels of organization* 93
- *Managing complexity in large-scale complex systems* 95
- *Systems engineering paradigms* 96
    - *Problem-solving paradigm* 97
    - *Japanese continuous circular flow paradigm* 97
- *Complexity and systems engineering principles* 99
- *Systems engineering and innovation* 101
    - *The general problem-solving paradigm* 102
    - *Creativity and innovation in systems conception and design* 103
- *Models of systems engineering* 107
    - *Classic systems engineering, mid '80s* 107
    - *Classic systems engineering organization & method* 107
    - *Updating systems engineering* 109
    - *A contemporary SE ontology* 112

Summary & conclusions ... *113*
References ... *115*
Complex social system engineering ... 117
Abstract ... *117*
Introduction ... *118*
Investigative methodology ... *118*
Instinctual human behaviours ... *119*
The family and natural environment ... *119*
The modern "hunter and the gatherer" ... *119*
Social engineering in the UK ... *120*
Urbanization ... *121*
Homo sapiens and the city ... *122*
The media and social engineering ... *123*
Political correctness: an instrument of social engineering ... *125*
Progressive degradation ... *126*
Old kingdom societal and cultural development ... *129*
Socioeconomic systems engineering (seSE) ... *132*
Overview of contemporary SeSE ... *132*
Overview of globalization ... *134*
Societal systems engineering (SSE) ... *137*
Human motivation ... *137*
Understanding the human condition ... *138*
Societal systems engineering in the UK ... *139*
Societal systems engineering in the new kingdom of ancient egypt ... *140*
Summary and conclusions ... *145*
In place of social engineering ... *147*
References: ... *148*
Natural systems engineering ... 150
Abstract ... *150*
Levels of organization ... *151*
Learning from natural levels of organization ... *152*
Extending the "levels of organization" paradigm ... *152*
Levels of organization and layers of systems engineering ... *154*
The triune brain ... *156*
Layers in the brain ... *156*
Levels of organization within the brain ... *157*
Brain cells for concepts ... *158*
Homeostasis ... *161*
Control through feedback ... *161*
Social insects and social organization ... *164*
Hymenoptera, honey bees ... *164*
Hymenoptera, ants ... *165*
Blattodea (formerly Isoptera), termites ... *167*
Do we have anything to learn from the social insects? ... *167*

Conclusions *169*
References *171*
System engineering architectonics **173**
The missing science *173*
Aspiring architectures *174*
Animal architectures *175*
Architecture's mission *176*
Kinds of architecture *177*
Layered architecture *177*
Layered architecture and mathematics *178*
Clustered architecture *180*
Getting to grip with complexity **182**
Preface *182*
Understanding complexity *184*
Introducing complexity *184*
Questions of complexity 184
Bak & Chen’s self-organized criticality 185
Complexity, science and engineering 186
Components of complexity? 186
Variety *187*
Generation of variety 187
Energy, source of variety 187
Variety 188
Minimum variety 188
Useful variety 190
Limited variety 191
Connectivity *192*
About connections 192
Reachability 193
Transitivity 194
Complex behaviour 194
Bounded, stable chaos 196
Connection strategies 197
Connection symmetry and simplicity 198
Connections and control 200
Control in action 201
Connections and synergy 202
Synergy 203
Disorder *204*
Entropy, measure of disorder 204
Configuration entropy 205
How might order develop naturally from disorder? 206
Viable pattern development 207
Reducing lattice energy 209

Feeling the penny drop....210
Summary....211
Getting a handle on complexity....212
Systems thinking....212
Models and vantage points....212
Models....213
A system model....214
Definitions of "system"....214
Upwards and outwards — Simple nested systems....216
Simultaneous multiple containment....217
Ideas of closure and completeness....218
CLMs and Completeness....220
Positives from negatives....221
Pairwise comparison to reveal hidden structure....223
Developing a standard approach....224
The generic reference model....226
Generic reference (function) model....227
Mission management....227
Viability management....228
Resource management....228
Generic reference (form) model....229
Structure....229
Influence....229
Potential....229
Sensation interpretation....230
Belief system....230
Behaviour selection....230
Response stimulation....231
Mission and behaviour models — Interactions....232
Thinking in loops....233
Counter-intuitive dynamic behaviour....234
Finding the common exchange medium....236
Thinking in straight lines — Occam's razor....237
Example of GRM in action....237
Vantage points....241
Third-person vantage point....241
Temporal vantage — Project VS functional organization....242
Temporal vantage — Successive fashions....243
The outsourcing dilemma....244
Analogical vantage....245
Summary....246
The social genotype....246
Models of evolution....246
Increasing natural order....247

Food and Inheritance....247
Closed double helix — Dynamic model....248
Double helix dynamic stability....249
Abstracting the closed double helix....251
The social genotype....253
Identity, individuality, pattern, culture....253
Social genotype — The concept....254
Rôles and stereotypes....254
Rôles and relationships....255
Social/organizational "genotypes"....256
Transcendental genotypes....256
Reinforcing the transcendental genotype....257
Beliefs and behaviours....259
Belief systems and behaviour....259
Locking to a genotype — Immune response....261
Immune suppression....263
The recurring theme....263
Ideologies....264
Belief system model....265
Developing the belief system model....266
The belief system battle....267
Running the model....270
Command and control....272
Towards a theory of complexity....275
Stability and chaos....275
Dynamic systems model....276
Sources and generators of complexity....276
Natural and man-made environments....277
Stability....279
Stability in open Systems....280
Open systems can oscillate without feedback....281
Bounded stable chaos and Poincaré Maps....281
Chaotic systems at work....284
Chaotic stability....284
Chaotic stability simulation....285
Chaos — Essential for life and evolution?....286
Variety, synthesis and decomposition....287
Free market competition....288
The dynamics of order and disorder....289
Towards a theory of complexity....289
Open systems interactions....290
Nature and the second law....292
The unified systems hypothesis (HUSH)....293
The principle of system reactions....293

The principle of system cohesion....294
The principle of system adaptation....294
The principle of connected variety....294
The principle of limited variety....295
The principle of preferred patterns....295
The principle of cyclic progression....296
HUSH Map....296
Notional open, interacting systems life-cycle....301
HUSH Map dynamic simulation....302
A law of entropic cycling....302
The law of entropic cycling....303
Seeing through the dark glass....304
References....306
Command & control....308
Decision making....308
The nature of decisions....308
Decision-makers biases....308
What is a "good" decision?....309
The C2 decision circle....310
Satisficing....311
Decision paradigm clash....312
Decisions and synthetic environments....313
Decision-making — man or machine?....313
Conflict management....317
Human behaviour....317
What's It about?....317
Command in history....318
What makes an effective fighting force?....319
Expectations of command and control....319
A view of the defensive C2 task....320
Command and control and "force multiplier effect"....320
The command and control (C2) design issue....321
Viewpoints....321
Deterministic viewpoint....323
Human viewpoint....325
Non-linear dynamic viewpoint....327
About cybernetic....331
History....331
What is information....338
Information theory....342
About systemic governance....346
System governance....350
About system governance....350
Steering....352

Staying on course.......353
Steering framework.......354
System Definition.......355
System governance.......355
System goals and course set.......356
The art of steering.......357
System correction and adaptation.......357
Complexity of system management, governance and adaptation.......358
Why innovation fails?.......359
Why transformation fails?.......359
Thinking about the system.......359
Paradigm to crumbling paradigm.......360
Law of diminishing returns.......362
Systemic balance.......363
Resilience.......364
About resilience.......364
Resilience structure.......369
System governance.......372
Resilience system governance framework.......375
The system.......377
Basin of attraction.......377
Threshold.......379
Regime.......381
High-low resilience.......382
How fast and large are resilience threshold shifts?.......383
Is it possible to reverse resilience threshold shifts?.......383
How can we prevent resilience threshold shifts?.......384
System performance.......384
Stability landscape.......387
Feedback.......390
Measuring resilience.......392
Vulnerability and resilience.......395
Transformability.......395
Leverage.......397
Adaptability and adaptive cycles.......399
Viability.......401
About viability.......401
Implementation.......403
Co-ordination.......403
Control.......403
Intelligence.......403
Policy.......404
Viable System Model (VSM).......404
Components of the viable system model.......405

    Key relationship with VSM ... *408*
  Normative management ... *408*
    Normative management functions: ... *409*
    Normative Management Function Efficacy: ... *410*
  Strategic management ... *410*
  Operation management ... *410*
 Purpose mission vision ... 411
 Systemic and system performance ... 413
  About system performance ... *413*
  System throughput ... *415*
About systems ... 419
 Introduction ... 419
 System behavior ... 421
 System dynamics ... 423
  About system dynamics ... *423*
    Stock and flow diagrams ... *424*
  System dynamics analysis ... *425*
    System dynamics steps ... *426*
  Stock and flow modelling ... *430*
    Understanding stock flow diagram ... *434*
  Causal loop ... *435*
    System Archetypes ... *436*
    Feedback loops ... *437*
 Constraints ... 446
 Feedback ... 448
    Understanding feedback characteristics enables efficient design of feedback: ... *451*
    Causal Relationship related to Feedback Using System Model ... *453*
 Variety engineering ... 454
  Variety Attenuators ... *455*
  Variety Amplifiers ... *455*
  Managing variety ... *456*
 Recursive systems ... 463
 Viable system model (VSM) ... 465
  Components of the viable system model ... *466*
  Key relationship with VSM ... *469*
Governance mangement framework ... 469
 Introduction ... 469
 System architecture blueprint ... 474
  System definition ... *474*
  Systemic attributes ... *480*
  Systemic variables ... *481*
 Systemic control tower ... 485
 System steering and adaptation ... 493
  Introduction ... *493*

        Innovation and transformation...494
        Team synergy – sinergia of what to what...497
            Reasons for failure:..498
            Team syntegrity...500
Models to realization...510
    Introduction...510
    Process management...511
    Information technology from a systemic perspective...513
Further reading...517
Acknowledgement...518

Prerequisite

Critical thinking

Foreword

> “The unexamined life is not worth living”
>
> — Socrates
>
> “Critical thinking is self-guided, self-disciplined thinking which attempts to reason at the highest level of quality in a fair-minded way. People who think critically attempt, with consistent and conscious effort, to live rationally, reasonably, and emphatically. They are keenly aware of the inherently flawed nature of human thinking when left unchecked.
>
> They strive to diminish the power of their egocentric and socio-centric tendencies. They use the intellectual tools that critical thinking offers – concepts and principles that enable them to analyze, assess, and improve thinking. They work diligently to develop the intellectual virtues of intellectual integrity, intellectual humility, intellectual civility, intellectual empathy, intellectual sense of justice and confidence in reason.
>
> They realize that no matter how skilled they are as thinkers, they can always improve their reasoning abilities and they will at times fall prey to mistakes in reasoning, human irrationality, prejudices, biases, distortions, uncritically accepted social rules and taboos, self-interest, and vested interest.
>
> They strive to improve the world in whatever ways they can and contribute to a more rational, civilized society. At the same time, they recognize the complexities often inherent in doing so. They strive never to think simplistically about complicated issues and always to consider the rights and needs of relevant others.
>
> They recognize the complexities in developing as thinkers, and commit themselves to life-long practice toward self-improvement. They embody the Socratic principle: The unexamined life is not worth living, because they realize that many unexamined lives together result in an uncritical, unjust, dangerous world.”
>
> — Linda Elder, September, 2007

Content Is thinking, thinking is content

The first and most important insight necessary for the appropriate design of instruction and curriculum is that content is, in the last analysis, nothing more nor less than a mode of thinking. Let me explain.

There are many ways to begin to grasp the profound truth that all content is nothing more nor less than a mode of thinking (about something), a way of figuring something out, a way of understanding something through thought. Here are just three ways of beginning to grasp this truth:

1. **All "content" in school is content in a subject.** All subjects are areas of study. All areas of study are "things" that we are interested in "figuring out". All fields of study have been advanced insofar as we have discovered ways to figure out whatever is being studied. There is no way to figure out something without thinking. There is no way to learn how to figure something out without learning how to think it through. There is no way to learn mathematical content without learning how to figure out correct answers to mathematical questions and problems. There is no way to learn historical content without learning how to figure out correct or reasonable answers to historical questions and problems. There is no way to learn biological content without learning how to figure out answers to biological questions and problems. Any subject or "content area" can therefore be understood as a mode of figuring out correct or reasonable answers to a certain body of questions. We study chemistry to figure out chemicals (to answer questions about chemicals). We study psychology to figure out people (to answer questions about certain human problems). All subjects can be understood best in this way.
2. **All "content" involves concepts.** There is no way to learn a body of content without learning the concepts which define and structure it. There is no way to learn a concept without learning how to use it in thinking something through. Hence, to learn the concept of democracy is to learn how to figure out whether some group is functioning democratically or not. To learn the concept of fair play is to learn how to figure out whether someone is being fair in the manner in which they are participating in a game. To learn the concept of a novel is to learn how to distinguish a novel from a play or short story. To learn the concept of a family is to learn how to distinguish a family from a gang or club. To learn any body of content, therefore, it is necessary to learn to think accurately and reasonably with the concepts that define the content.

3. **All "content" is logically interdependent.** To understand one part of some content requires that we figure out its relation to other parts of that content.

For example, we understand what a scientific experiment is only when we understand what a scientific theory is. We understand what a scientific theory is only when we understand what a scientific hypothesis is. We understand what a scientific hypothesis is only when we understand what a scientific prediction is. We understand what a scientific prediction is only when we understand what it is to scientifically test a view. We understand what it is to scientifically test a view only when we understand what a scientific experiment is. Etc....etc.....etc.... To learn any body of content, therefore, is to figure out (i.e., reason or think through) the connections between the parts of that content. There is no learning of the content without this thinking process.

To this point the majority of teachers and students approach content, not as a mode of thinking, not as a system for thought, or even as a system of thought, but rather as a sequence of stuff to be routinely "covered" and committed to memory. When content is approached in this lower order way, there is no basis for intellectual growth, no deep structures of knowledge formed, no basis for long term grasp and control.

Activated ignorance, activated knowledge

It is impossible to reason without using some set of facts, data, or experiences as a constituent part of one’s thinking. Finding trustworthy sources of information and refining one’s own experience critically are important goals of critical thinkers. We must be vigilant about the sources of information we use. We must be analytically critical of the use we make of our own experience. Experience may be the best teacher, but biased experience supports bias, distorted experience supports distortion, self-deluded experience supports self-delusion. We, therefore, must not think of our experience as sacred in any way but, instead, as one important dimension of thought that must, like all others, be critically analyzed and assessed.

The mind can take in information in three distinctive ways: (1) by internalizing inert information, (2) by forming activated ignorance, and (3) by achieving activated knowledge.

Inert Information

By inert information, we mean taking into the mind information that, though memorized, we do not understand-despite the fact that we think we do. For example, many people have taken in, during their schooling, a lot of information about democracy that leads them to believe they understand the concept. Often, a good part of the information they have internalized consists of empty verbal rituals in their mind. For example, many children learn in school that “democracy is government of the people, by the people, for the people." This catchy phrase often sticks in their mind. It leads them to think they understand what it means, though most of them do not translate it into any practical criteria for assessing the extent to which democracy does or does not exist in any given country. Most people, to be explicit, could not intelligibly answer any of the following questions:

1. What is the difference between a government of the people and a government for the people?
2. What is the difference between a government for the people and a government by the people?
3. What is the difference between a government by the people and a government of the people?
4. What exactly is meant by "the people?"

To generalize, students often do not sufficiently think about information they memorize in school sufficient to transform it into something meaningful in their mind. Much human information is, in the mind of the humans who possess it, merely empty words (inert or dead in the mind). Critical thinkers try to clear the mind of inert information by recognizing it as such and transforming it, through analysis, into something meaningful.

Activated ignorance

By activated ignorance, we mean taking into the mind, and actively using, information that is false, though we mistakenly think it to be true. The philosopher Rene Descartes came to confidently believe that animals have no actual feelings but are simply robotic machines. Based on this activated ignorance, he performed painful experiments on animals and interpreted their cries of pain as mere noises.

Some people believe, through activated ignorance, that they understand things, events, people, and situations that they do not. They act upon their false ideas, illusions, and misconceptions, often leading to needless waste, pain, and suffering. Sometimes activated ignorance is the basis for massive actions involving millions of people (think of the consequences of the Nazi idea that Germans were the master race and Jews an inferior race). Sometimes it is an individual misconception that is acted on only by one person in a limited number of settings. Wherever activated ignorance exists, it is dangerous.

It is essential, therefore, that we question our beliefs, especially when acting upon them has significant potential implications for the harm, injury, or suffering of others. It is reasonable to suppose that everyone has some beliefs that are, in fact, a form of activated ignorance.

Eliminating as many such beliefs as we can is a responsibility we all have. Consider automobile drivers who are confident they can drive safely while they are intoxicated. Consider the belief that smoking does not have any significant negative health effects.

It is not always easy to identify what is and is not activated ignorance. The concept of activated ignorance is important regardless of whether we can determine whether particular information we come across is false or misleading. What we need to keep in mind are clear-cut cases of activated ignorance so we have a clear idea of it, and personal vigilance with respect to the information we come across that is potentially false. Most people who have acted harmfully as a result of their activated ignorance have probably not realized that they were the agent of the suffering of others. Ignorance treated as the truth is no trivial matter.

Activated knowledge

By activated knowledge, we mean taking into the mind, and actively using, information that is not only true but that, when insightfully understood, leads us by implication to more and more knowledge.

Consider the study of history, for example. Many students do no more than memorize isolated statements in the history textbook so as to pass exams. Some of these statements-the ones they don’t understand and could not explain-become part of the students” battery of inert information. Other statements-the ones they misunderstand and wrongly explain-become part of the students” battery of activated ignorance. Much of the information, of course, is simply forgotten shortly after the exam.

What is importantly powerful, from a critical thinking perspective, is understanding the logic of historical thinking as a way of understanding the logic of history. When we understand history this way, our knowledge is activated. It enables us to build on historical knowledge by thinking through previous historical knowledge.

For example, we might begin by understanding the basic agenda of historical thinking: to construct a story or account of the past that enables us to better understand our present and make rational plans for the future. Once we have this basic knowledge of the logic of history, we are driven to recognize that we already engage in historical thinking in our daily life. We begin to see the connection between thinking within the subject and thinking in everyday life situations. For example, as a result of this provisional characterization of the logic of historical thinking, it is clear that all humans create our own story in the privacy of our mind. We use this story to make sense of our present, in the light of our conception of our past, and make plans for the future, given our understanding of our present and past. Most of us do not think of ourselves as doing this, however.

If we further reflect on our knowledge of the logic of history, and think through some of its implications, we become aware that there is a logical similarity, for example, between historical thinking and ordinary, everyday “gossip.” In gossip, we create a story about events in someone’s recent past and pass on our story to others. If we reflect further on the logic of history, we also recognize that every issue of a daily newspaper is produced by a kind of thinking analogous to historical thinking. In both cases someone is constructing accounts of the past presented as making sense of some set of events in time.

Further reflection on the logic of history should lead us to ask ourselves questions such as, “In creating an account of some time period, approximately what percentage of what actually took place finds its way into any given historical account?” This should lead us to discover that for any given historical period, even one as short as a day, countless events take place, with the implication that no historical account contains more than a tiny percentage of the total events within any given historical period. This should lead us to discover that historians must regularly make value judgments to decide what to include in, and what to exclude from, their accounts.

Upon further reflection, it should become apparent to us that there are different possible stories and accounts that highlight different patterns in the events themselves-for example, accounts that highlight “high-level” decision-makers (great-person accounts), in contrast to accounts that highlight different social and economic classes (social and economic histories). It then should be apparent to us that the specific questions that any given historical thinker asks depend on the specific agenda or goal of that thinker.

It also should be apparent that:

- The historical questions asked are what determine which data or events are relevant;
- One and the same event can be illuminated by different conceptualizations (for example, different political, social, and economic theories about people and social change);
- Different historians make different assumptions (each influencing the way they put their questions and the data that seem most important to them);
- When a given historian identifies with a given group of people and writes his or her history, it often highlights the positive characteristics of those people and the negative characteristics of those with whom they are or were in conflict.

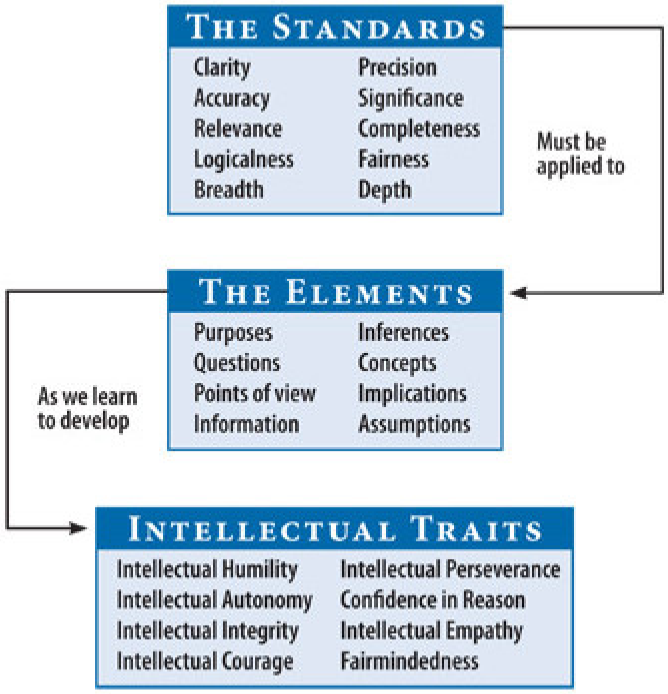
It is in virtue of “discoveries” and insights such as these — which we must think through for ourselves to truly grasp them as knowledge — that our view of history is transformed. They enable us to begin to “see through” historical texts. They lead us to value historical thinking, as its significance in everyday life becomes clear to us. They make more and more transparent to us our history, our use of history, and the effect of our use of history on the world and human welfare.

Activated knowledge, then, is knowledge born of dynamic seminal ideas that, when applied systematically to common experience, enable us to infer, by implication, further and further knowledge. Activated knowledge is potential in every legitimate human discipline. We begin with basic information about the most basic ideas and goals of a field. Grounded in basic concepts and first principles, we are able to experience the power of thought, knowledge, and experience working in unison. A habit of studying to learn to seek the logic of things is one of the most powerful ways to begin to discover activated knowledge. It is one of the most important keys to making lifelong learning an essential ingredient in one’s life.

Bases of critical thinking

Our conception of critical thinking is based on the substantive approach developed by Dr. Richard Paul and his colleagues at the Center and Foundation for Critical Thinking over multiple decades. It is relevant to every subject, discipline, and profession, and to reasoning through the problems of everyday life. It entails five essential dimensions of critical thinking:

1. The analysis of thought.
2. The assessment of thought.
3. The dispositions of thought.
4. The skills and abilities of thought.
5. The obstacles or barriers to critical thought.



At the left is an overview of the first three dimensions. In sum, the elements or structures of thought enable us to "take our thinking apart" and analyze it. The intellectual standards are used to assess and evaluate the elements. The intellectual traits are dispositions of mind embodied by the fair-minded critical thinker. To cultivate the mind, we need command of these essential dimensions, and we need to consistently apply them as we think through the many problems and issues in our lives.

> “The question is, do we govern the thought that governs us?”

To govern our thought that govern us, we need to discover the extent to which our thinking is bound by a culture. Cultures are good in many ways. But, to the extent that they lock us in to one way of looking at the world, we need to transcend them. We need to think beyond them.

Reversing the process so that we’re in the driver’s seat – so that we’re doing the thinking we need to do as well as we can – is what critical thinking is about.

The intellectual standards

The intellectual standards are the second dimension of critical thinking applied to the elements of reasoning.

Universal intellectual standards are standards which must be applied to thinking whenever one is interested in checking the quality of reasoning about a problem, issue, or situation. To think critically entails having command of these standards.

The ultimate goal, then, is for these questions to become infused in our thinking, forming part of our inner voice, which then guides us to better and better reasoning. While there are many universal standards, the following are some of the most essential:

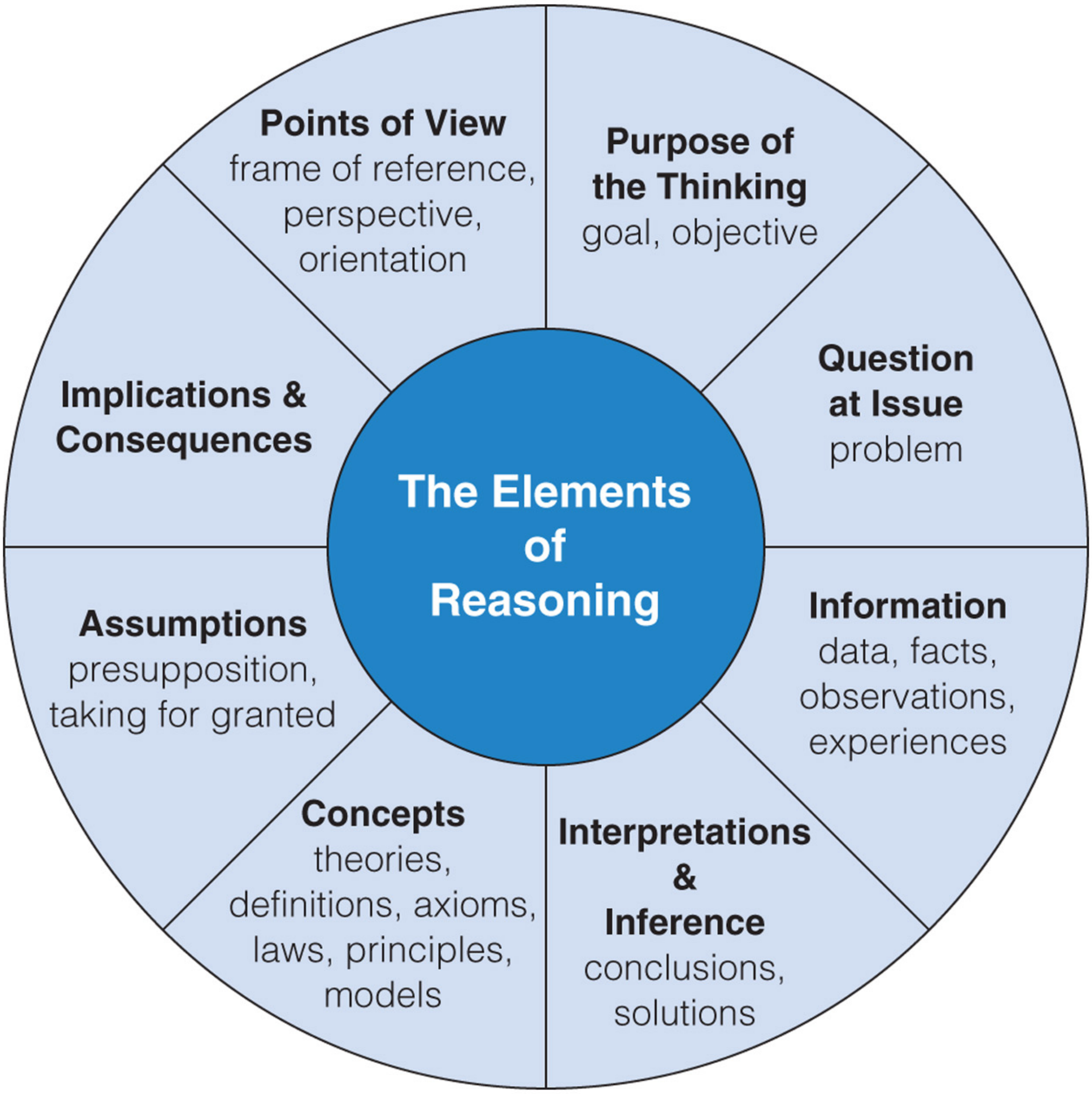
- **Clarity:** Clarity is the gateway standard. If a statement is unclear, we cannot determine whether it is accurate or relevant. In fact, we cannot tell anything about it because we don't yet know what it is saying. For example, the question, "What can be done about the education system in America?" is unclear. In order to address the question adequately, we would need to have a clearer understanding of what the person asking the question is considering the "problem" to be. A clearer question might be "What can educators do to ensure that students learn the skills and abilities which help them function successfully on the job and in their daily decision-making?"
- **Accuracy:** Is that really true? How could we check that? How could we find out if that is true? A statement can be clear but not accurate, as in "Most dogs are over 300 pounds in weight."
- **Precision**: Could you give more details? Could you be more specific?
  A statement can be both clear and accurate, but not precise, as in "Jack is overweight." (We don't know how overweight Jack is, one pound or 500 pounds.)
- **Relevance:** How is that connected to the question? How does that bear on the issue?
  A statement can be clear, accurate, and precise, but not relevant to the question at issue. For example, students often think that the amount of effort they put into a course should be used in raising their grade in a course. Often, however, the "effort" does not measure the quality of student learning; and when this is so, effort is irrelevant to their appropriate grade.
- **Depth:** How does your answer address the complexities in the question? How are you taking into account the problems in the question? Is that dealing with the most significant factors? A statement can be clear, accurate, precise, and relevant, but superficial (that is, lack depth). For example, the statement, "Just say No!" which is often

used to discourage children and teens from using drugs, is clear, accurate, precise, and relevant. Nevertheless, it lacks depth because it treats an extremely complex issue, the pervasive problem of drug use among young people, superficially. It fails to deal with the complexities of the issue.

- **Breadth**: Do we need to consider another point of view? Is there another way to look at this question? What would this look like from a conservative standpoint? What would this look like from the point of view of . . .? A line of reasoning may be clear accurate, precise, relevant, and deep, but lack breadth (as in an argument from either the conservative or liberal standpoint which gets deeply into an issue, but only recognizes the insights of one side of the question.)
- **Logic**: Does this really make sense? Does that follow from what you said? How does that follow? But before you implied this, and now you are saying that; how can both be true? When we think, we bring a variety of thoughts together into some order. When the combination of thoughts are mutually supporting and make sense in combination, the thinking is "logical." When the combination is not mutually supporting, is contradictory in some sense or does not "make sense," the combination is not logical.
- **Fairness**: Do I have a vested interest in this issue? Am I sympathetically representing the viewpoints of others? Human think is often biased in the direction of the thinker - in what are the perceived interests of the thinker. Humans do not naturally consider the rights and needs of others on the same plane with their own rights and needs. We therefore must actively work to make sure we are applying the intellectual standard of fairness to our thinking. Since we naturally see ourselves as fair even when we are unfair, this can be very difficult. A commitment to fair-mindedness is a starting place.

The elements of reasoning

Elements of reasoning or elements of thoughts are the first dimension of critical thinking, applied by the intellectual standards.


The Elements of Reasoning
Purpose of the Thinking
goal, objective
Question at Issue
problem
Information
data, facts, observations, experiences
Interpretations & Inference
conclusions, solutions
Concepts
theories, definitions, axioms, laws, principles, models
Assumptions
presupposition, taking for granted
Implications & Consequences
Points of View
frame of reference, perspective, orientation

Once we progress from thought which is purely associational and undisciplined, to thinking which is conceptual and inferential, thinking which attempts in some intelligible way to figure something out — in short, to reasoning — then it is helpful to concentrate on what can be called "the elements of reasoning." The elements of reasoning are those essential dimensions of reasoning whenever and wherever it occurs. Working together, they shape reasoning and provide a general logic to the use of reason.

We can articulate these elements by paying close attention to what is implicit in the act of figuring anything out by the use of reason. These elements, then — purpose, question at issue, assumptions, inferences, implications, point of view, concepts and evidence — constitute a central focus in the assessment of a person thinking.

The basic conditions implicit whenever we gather, conceptualize, apply, analyze, synthesize, or evaluate information — the elements of reasoning — are as follows:

1. **Purpose, Goal, or End in View:** Whenever we reason, we reason to achieve some objective, to satisfy some desire or fulfil some need. One source of problems in people reasoning is traceable to defects at the level of goal, purpose, or end. If the goal is unrealistic, for example, or contradictory to other goals the person has, if it is confused or muddled in some way, then the reasoning used to achieve it is problematic.
2. **Question at Issue, or Problem to be Solved:** Whenever we attempt to reason something out, there is at least one question at issue, at least one problem to be solved. One area of concern for assessing a person to reason, therefore, will be the formulation of the question to be answered or problem to be solved, whether with respect to the person's own reasoning or to that of others.
3. **Point of view, or frame of reference:** Whenever we reason, we must reason within some point of view or frame of reference. Any "defect" in that point of view or frame of reference is a possible source of problems in the reasoning. A point of view may be too narrow, too parochial; may be based on false or misleading analogies or metaphors; may contain contradictions, and so forth. It may be restricted or unfair. A self feedback would involve commentary noting both when we meet the standards and when we fail to meet them. Evaluation of our ability to handle the dimension of point of view would also appropriately direct ourselves to lines of reasoning that would promote a richer facility in reasoning about, and in terms of, points of view.
4. **The empirical dimension of reasoning:** Whenever we reason, there is some "stuff," some phenomena or informations about which we are reasoning. Any "defect," then, in the experiences, data, evidence, or raw material upon which a person's reasoning is based is a possible source of problems. We should assess and feedback ourselves on our ability to give evidence that is gathered and reported clearly, fairly, and accurately. Does we furnish data at all? Is the data relevant? Is the information adequate for achieving the defined purpose? Is it applied consistently, or do we distort it to fit our own point of view?
5. **Inferences:** Reasoning proceeds by steps in which we reason as follows: "Because this is so, that also is so (or probably so)," or "Since this, therefore that." Any "defect" in such inferences is a possible problem in our reasoning.

6. **The conceptual dimension of reasoning:** All reasoning uses some ideas or concepts and not others. These concepts can include the theories, principles, axioms and rules implicit in our reasoning. Any "defect" in the concepts or ideas of the reasoning is a possible source of problems in student reasoning.
   A self feedback would note whether our understanding of theories and rules was deep or merely superficial. Are the concepts we use in our reasoning clear ones? Are our ideas relevant to the issue at hand, are our principles slanted by our point of view?
7. **Implications and consequences:** No matter where we stop our reasoning, it will always have further implications and consequences. As reasoning develops, statements will logically be entailed by it. Any "defect" in the implications or consequences of our reasoning is a possible source of problems. The ability to reason well is measured in part by an ability to understand and enunciate the implications and consequences of the reasoning. We therefore need help in coming to understand both the relevant standards of reasoning out implications and the degree to which our own reasoning meets those standards.
8. **Assumptions:** All reasoning must begin somewhere, must take some things for granted. Any "defect" in the assumptions or presuppositions with which the reasoning begins is a possible source of problems. Assessing skills of reasoning involves assessing our ability to recognize and articulate our assumptions, again according to the relevant standards. An assumption may be stated clearly or unclearly; an assumption may be justifiable or unjustifiable, crucial or extraneous, consistent or contradictory. A self feedback on our ability to meet the relevant standards is a large factor in the improvement of our reasoning.

Intellectual traits

Valuable intellectual traits are developed or programmed as we learn to use the intellectual standards applied to the elements of reasoning.

- **Intellectual humility:** Having a consciousness of the limits of one's knowledge, including a sensitivity to circumstances in which one's native egocentrism is likely to function self-deceptively; sensitivity to bias, prejudice and limitations of one's viewpoint. Intellectual humility depends on recognizing that one should not claim more than one actually knows. It does not imply spinelessness or submissiveness. It implies the lack of intellectual pretentiousness, boastfulness, or conceit, combined with insight into the logical foundations, or lack of such foundations, of one's beliefs.

- **Intellectual courage:** Having a consciousness of the need to face and fairly address ideas, beliefs or viewpoints toward which we have strong negative emotions and to which we have not given a serious hearing. This courage is connected with the recognition that ideas considered dangerous or absurd are sometimes rationally justified (in whole or in part) and that conclusions and beliefs inculcated in us are sometimes false or misleading. To determine for ourselves which is which, we must not passively and uncritically "accept" what we have "learned." Intellectual courage comes into play here, because inevitably we will come to see some truth in some ideas considered dangerous and absurd, and distortion or falsity in some ideas strongly held in our social group. We need courage to be true to our own thinking in such circumstances. The penalties for non-conformity can be severe.
- **Intellectual empathy:** Having a consciousness of the need to imaginatively put oneself in the place of others in order to genuinely understand them, which requires the consciousness of our egocentric tendency to identify truth with our immediate perceptions of long-standing thought or belief. This trait correlates with the ability to reconstruct accurately the viewpoints and reasoning of others and to reason from premises, assumptions, and ideas other than our own. This trait also correlates with the willingness to remember occasions when we were wrong in the past despite an intense conviction that we were right, and with the ability to imagine our being similarly deceived in a case-at-hand.
- **Intellectual autonomy:** Having rational control of one's beliefs, values, and inferences. The ideal of critical thinking is to learn to think for oneself, to gain command over one's thought processes. It entails a commitment to analyzing and evaluating beliefs on the basis of reason and evidence, to question when it is rational to question, to believe when it is rational to believe, and to conform when it is rational to conform.
- **Intellectual integrity:** Recognition of the need to be true to one's own thinking; to be consistent in the intellectual standards one applies; to hold one's self to the same rigorous standards of evidence and proof to which one holds one's antagonists; to practice what one advocates for others; and to honestly admit discrepancies and inconsistencies in one's own thought and action.
- **Intellectual perseverance:** Having a consciousness of the need to use intellectual insights and truths in spite of difficulties, obstacles, and frustrations; firm adherence to rational principles despite the irrational opposition of others; a sense of the need to struggle with confusion and unsettled questions over an extended period of time to achieve deeper understanding or insight.

- **Confidence in reason**: Confidence that, in the long run, one's own higher interests and those of humankind at large will be best served by giving the freest play to reason, by encouraging people to come to their own conclusions by developing their own rational faculties; faith that, with proper encouragement and cultivation, people can learn to think for themselves, to form rational viewpoints, draw reasonable conclusions, think coherently and logically, persuade each other by reason and become reasonable persons, despite the deep-seated obstacles in the native character of the human mind and in society as we know it.
- **Fairmindedness**: Having a consciousness of the need to treat all viewpoints alike, without reference to one's own feelings or vested interests, or the feelings or vested interests of one's friends, community or nation; implies adherence to intellectual standards without reference to one's own advantage or the advantage of one's group.

Becoming a critic of your thinking

There is nothing more practical than sound thinking. No matter what your circumstance or goals, no matter where you are, or what problems you face, you are better off if your thinking is skilled. As a manager, leader, employee, citizen, lover, friend, parent — in every realm and situation of your life — good thinking pays off. Poor thinking, in turn, inevitably causes problems, wastes time and energy, engenders frustration and pain.

Critical thinking is the disciplined art of ensuring that you use the best thinking you are capable of in any set of circumstances. The general goal of thinking is to “figure out the lay of the land” in any situation we are in. We all have multiple choices to make. We need the best information to make the best choices.

What is really going on in this or that situation? Are they trying to take advantage of me? Does so-and-so really care about me? Am I deceiving myself when I believe that . . . ? What are the likely consequences of failing to . . . ? If I want to do . . . , what is the best way to prepare for it? How can I be more successful in doing . . . ? Is this my biggest problem, or do I need to focus my attention on something else?

Successfully responding to such questions is the daily work of thinking. However, to maximize the quality of your thinking, you must learn how to become an effective "critic" of your thinking. And to become an effective critic of your thinking, you have to make learning about thinking a priority.

Ask yourself these — rather unusual — questions: What have you learned about how you think? Did you ever study your thinking? What do you know about how the mind processes information? What do you really know about how to analyze, evaluate, or reconstruct your thinking? Where does your thinking come from? How much of it is of “good” quality? How much of it is of “poor” quality? How much of your thinking is vague, muddled, inconsistent, inaccurate, illogical, or superficial? Are you, in any real sense, in control of your thinking? Do you know how to test it? Do you have any conscious standards for determining when you are thinking well and when you are thinking poorly? Have you ever discovered a significant problem in your thinking and then changed it by a conscious act of will? If anyone asked you to teach them what you have learned, thus far in your life, about thinking, would you really have any idea what that was or how you learned it?

If you are like most, the only honest answers to these questions run along the lines of, “Well, I suppose I really don’t know much about my thinking or about thinking in general. I suppose in my life I have more or less taken my thinking for granted. I don’t really know how it works. I have never really studied it. I don’t know how I test it, or even if I do test it. It just happens in my mind automatically.“

It is important to realize that serious study of thinking, serious thinking about thinking, is rare. It is not a subject in most colleges. It is seldom found in the thinking of our culture. But if you focus your attention for a moment on the role that thinking is playing in your life, you may come to recognize that, in fact, everything you do, or want, or feel is influenced by your thinking. And if you become persuaded of that, you will be surprised that humans show so little interest in thinking.

To make significant gains in the quality of your thinking you will have to engage in a kind of work that most humans find unpleasant, if not painful — intellectual work. Yet once this thinking is done and we move our thinking to a higher level of quality, it is not hard to keep it at that level. Still, there is the price you have to pay to step up to the next level. One doesn’t become a skilful critic of thinking over night, any more than one becomes a skilful basketball player or musician over night. To become better at thinking, you must be willing to put the work into thinking that skilled improvement always requires.

This means you must be willing to practice special “acts” of thinking that are initially at least uncomfortable, and sometimes challenging and difficult. You have to learn to do with your mind “moves” analogous to what accomplished athletes learn to do (through practice and feedback) with their bodies. Improvement in thinking, in other words, is similar to improvement in other domains of performance where progress is a product of sound theory, commitment, hard work, and practice.

Consider the following key ideas, which, when applied, result in a mind practicing skilled thinking. These ideas represent just a few of the many ways in which disciplined thinkers actively apply theory of mind to the mind by the mind in order to think better. In these examples, we focus on the significance of thinking clearly, sticking to the point (thinking with relevance), questioning deeply, and striving to be more reasonable. For each example, we provide a brief overview of the idea and its importance in thinking, along with strategies for applying it in life. Realize that the following ideas are immersed in a cluster of ideas within critical thinking. Though we chose these particular ideas, many others could have instead been chosen. There is no magic in these specific ideas. In short, it is important that you understand these as a sampling of all the possible ways in which the mind can work to discipline itself, to think at a higher level of quality, to function better in the world.

Clarify your thinking

Be on the look-out for vague, fuzzy, formless, blurred thinking. Try to figure out the real meaning of what people are saying. Look on the surface. Look beneath the surface. Try to figure out the real meaning of important news stories. Explain your understanding of an issue to someone else to help clarify it in your own mind. Practice summarizing in your own words what others say. Then ask them if you understood them correctly. You should neither agree nor disagree with what anyone says until you (clearly) understand them.

Our own thinking usually seems clear to us, even when it is not. But vague, ambiguous, muddled, deceptive, or misleading thinking are significant problems in human life. If we are to develop as thinkers, we must learn the art of clarifying thinking, of pinning it down, spelling it out, and giving it a specific meaning. Here’s what you can do to begin. When people explain things to you, summarize in your own words what you think they said. When you cannot do this to their satisfaction, you don’t really understand what they said. When they cannot summarize what you have said to your satisfaction, they don’t really understand what you said.

Try it. See what happens.

Strategies for clarifying your thinking.

- State one point at a time.
- Elaborate on what you mean.
- Give examples that connect your thoughts to life experiences .
- Use analogies and metaphors to help people connect your ideas to a variety of things they already understand (for example, critical thinking is like an onion. There are many layers to it. Just when you think you have it basically figured out, you realize there is another layer, and then another, and another and another and on and on).

Here is one format you can use.

- I think . . . (state your main point).
- In other words . . . (elaborate your main point).
- For example . . . (give an example of your main point).
- To give you an analogy . . . (give an illustration of your main point).

To clarify other people's thinking, consider asking the following.

- Can you restate your point in other words? I didn't understand you.
- Can you give an example?
- Let me tell you what I understand you to be saying. Did I understand you correctly?

Stick to the point

Be on the lookout for fragmented thinking, thinking that leaps about with no logical connections. Start noticing when you or others fail to stay focused on what is relevant. Focus on finding what will aid you in truly solving a problem. When someone brings up a point (however true) that doesn't seem pertinent to the issue at hand, ask, "How is what you are saying relevant to the issue?" When you are working through a problem, make sure you stay focused on what sheds light on and, thus, helps address the problem. Don't allow your mind to wander to unrelated matters. Don't allow others to stray from the main issue. Frequently ask: "What is the central question? Is this or that relevant to it? How?"

When thinking is relevant, it is focused on the main task at hand. It selects what is germane, pertinent, and related. It is on the alert for everything that connects to the issue. It sets aside what is immaterial, inappropriate, extraneous, and beside the point. What is relevant directly bears upon (helps solve) the problem you are trying to solve. When thinking drifts away from what is relevant, it needs to be brought back to what truly makes a difference. Undisciplined thinking is often guided by associations (this reminds me of that, that reminds me of this other thing) rather than what is logically connected ("If a and b are true, then c must also be true"). Disciplined thinking intervenes when thoughts wander from what is pertinent and germane concentrating the mind on only those things that help it figure out what it needs to figure out.

Ask these questions to make sure thinking is focused on what is relevant

- Am I focused on the main problem or task?
- How is this connected? How is that?
- Does my information directly relate to the problem or task?
- Where do I need to focus my attention?

- Are we being diverted to unrelated matters?
- Am I failing to consider relevant viewpoints?
- How is your point relevant to the issue we are addressing?
- What facts are actually going to help us answer the question? What considerations should be set aside?
- Does this truly bear on the question? How does it connect?

Question questions

Be on the lookout for questions. The ones we ask. The ones we fail to ask. Look on the surface. Look beneath the surface. Listen to how people question, when they question, when they fail to question. Look closely at the questions asked. What questions do you ask, should you ask? Examine the extent to which you are a questioner, or simply one who accepts the definitions of situations given by others.

Most people are not skilled questioners. Most accept the world as it is presented to them. And when they do question, their questions are often superficial or “loaded.” Their questions do not help them solve their problems or make better decisions. Good thinkers routinely ask questions in order to understand and effectively deal with the world around them. They question the status quo. They know that things are often different from the way they are presented. Their questions penetrate images, masks, fronts, and propaganda. Their questions make real problems explicit and discipline their thinking through those problems. If you become a student of questions, you can learn to ask powerful questions that lead to a deeper and more fulfilling life. Your questions become more basic, essential, and deep.

Strategies for formulating more powerful questions

- Whenever you don’t understand something, ask a question of clarification.
- Whenever you are dealing with a complex problem, formulate the question you are trying to answer in several different ways (being as precise as you can) until you hit upon the way that best addresses the problem at hand.
- Whenever you plan to discuss an important issue or problem, write out in advance the most significant questions you think need to be addressed in the discussion. Be ready to change the main question, but once made clear, help those in the discussion stick to the question, making sure the dialogue builds toward an answer that makes sense.

Questions you can ask to discipline your thinking

- What precise question are we trying to answer?
- Is that the best question to ask in this situation?
- Is there a more important question we should be addressing?
- Does this question capture the real issue we are facing?
- Is there a question we should answer before we attempt to answer this question?
- What information do we need to answer the question?
- What conclusions seem justified in light of the facts?
- What is our point of view? Do we need to consider another?
- Is there another way to look at the question?
- What are some related questions we need to consider?
- What type of question is this: an economic question, a political question, a legal question, etc...?

Be reasonable

Be on the lookout for reasonable and unreasonable behaviors — yours and others. Look on the surface. Look beneath the surface. Listen to what people say. Look closely at what they do. Notice when you are unwilling to listen to the views of others, when you simply see yourself as right and others as wrong. Ask yourself at those moments whether their views might have any merit. See if you can break through your defensiveness to hear what they are saying. Notice unreasonableness in others. Identify times when people use language that makes them appear reasonable, though their behavior proves them to be otherwise. Try to figure out why you, or others, are being unreasonable. Might you have a vested interested in not being open-minded? Might they?

One of the hallmarks of a critical thinker is the disposition to change one's mind when given good reason to change. Good thinkers want to change their thinking when they discover better thinking. They can be moved by reason. Yet, comparatively few people are reasonable. Few are willing to change their minds once set. Few are willing to suspend their beliefs to fully hear the views of those with which they disagree. How would you rate yourself?

Strategies for becoming more reasonable

Say aloud, "I'm not perfect. I make mistakes. I'm often wrong." See if you have the courage to admit this during a disagreement: "Of course, I may be wrong. You may be right."

Practice saying in your own mind, “I may be wrong. I often am. I’m willing to change my mind when given good reasons.” Then look for opportunities to make changes in your thinking.

Ask yourself, “When was the last time I changed my mind because someone gave me better reasons for his (her) views than I had for mine?” To what extent are you open to new ways of looking at things? To what extent can you objectively judge information that refutes what you already think?

Realize that you are being close-minded if you:

a) Are unwilling to listen to someone’s reasons.

b) Are irritated by the reasons people give you.

c) Become defensive during a discussion.

After you catch yourself being close-minded, analyze what was going on in your mind by completing these statements:

a) I realize I was being close-minded in this situation because . . .

b) The thinking I was trying to hold onto is . . .

c) Thinking that is potentially better is . . .

d) This thinking is better because . . .

In closing, let me remind you that the ideas in this article are a very few of the many ways in which critical thinkers bring intellectual discipline to bear upon their thinking. The best thinkers are those who understand the development of thinking as a process occurring throughout many years of practice in thinking. They recognize the importance of learning about the mind, about thoughts, feelings and desires and how these functions of the mind interrelate. They are adept at taking thinking apart, and then assessing the parts when analyzed. In short, they study the mind, and they apply what they learn about the mind to their own thinking in their own lives.

The extent to which any of us develops as a thinker is directly determined by the amount of time we dedicate to our development, the quality of the intellectual practice we engage in, and the depth, or lack thereof, of our commitment to becoming more reasonable, rational, successful persons.

Thinking gets us into trouble because we often:

- Jump to conclusions.
- Fail to think-through implications.

- Lose track of their goal.
- Are unrealistic.
- Focus on the trivial.
- Fail to notice contradictions.
- Accept inaccurate information.
- Ask vague questions.
- Give vague answers.
- Ask loaded questions.
- Ask irrelevant questions.
- Confuse questions of different types.
- Answer questions we are not competent to answer.
- Come to conclusions based on inaccurate or irrelevant information.
- Ignore information that does not support our view.
- Make inferences not justified by our experience.
- Distort data and state it inaccurately.
- Fail to notice the inferences we make.
- Come to unreasonable conclusions.
- Fail to notice our assumptions.
- Often make unjustified assumptions.
- Miss key ideas.
- Use irrelevant ideas.
- Form confused ideas.
- Form superficial concepts.
- Misuse words.
- Ignore relevant viewpoints.
- Cannot see issues from points of view other than our own.

- Confuse issues of different types.
- Are unaware of our prejudices.
- Think narrowly.
- Think imprecisely.
- Think illogically.
- Think one-sidedly.
- Think simplistically.
- Think hypocritically.
- Think superficially.
- Think ethnocentrically.
- Think egocentrically.
- Think irrationally.
- Do poor problem solving.
- Make poor decisions.
- Are poor communicators.
- Have little insight into our own ignorance.

A how-to list for dysfunctional living

Most people have no notion of what it means to take charge of their lives. They don't realize that the quality of their lives depends on the quality of their thinking. We all engage in numerous dysfunctional practices to avoid facing problems in our thinking. Consider the following and ask yourself how many of these dysfunctional ways of thinking you engage in:

1. Surround yourself with people who think like you. Then no one will criticize you.
2. Don't question your relationships. You then can avoid dealing with problems within them.
3. If critiqued by a friend or lover, look sad and dejected and say, "I thought you were my friend!" or "I thought you loved me!".

4. When you do something unreasonable, always be ready with an excuse. Then you won't have to take responsibility. If you can't think of an excuse, look sorry and say, "I can't help how I am!".
5. Focus on the negative side of life. Then you can make yourself miserable and blame it on others.
6. Blame others for your mistakes. Then you won't have to feel responsible for your mistakes. Nor will you have to do anything about them.
7. Verbally attack those who criticize you. Then you don't have to bother listening to what they say.
8. Go along with the groups you are in. Then you won't have to figure out anything for yourself.
9. Act out when you don't get what you want. If questioned, look indignant and say, "I'm just an emotional person. At least I don't keep my feelings bottled up!".
10. Focus on getting what you want. If questioned, say, "If I don't look out for number one, who will?".

As you see, the list is almost laughable. And so it would be if these irrational ways of thinking didn't lead to problems in life. But they do. And often. Only when we are faced with the absurdity of dysfunctional thinking, and can see it at work in our lives, do we have a chance to alter it. The strategies outlined in this guide presuppose your willingness to do so.

System mindset

Introduction

I want to show you that we live in a mechanical world and remind you that physical reality operates in the same way, everywhere, all the time. From this, I'll describe a simple life posture, one which you can improve every area of your life.

> **"You probably want control of your life along with more clarity."**

Most people don't master this skill, so they struggle. In these pages I want to convince you that your life is not an endless stream of erratic occurrences. Rather, it's a finite collection of logical, individual systems that are constantly at work producing the ongoing results of your life. This elementary yet profound insight will arrive suddenly, at a specific moment in time, and then it will be with you always. I call this epiphany "getting it."

There's nothing mystical here. It makes complete sense, and it's all rooted in how the simple mechanics of the physical world is currently functioning. It's in the physics of it all — the reality of up and down and back and forth, of movement, of breathing, of gravity, and of the same actions leading to the same results.

It's a good time to list some preferred synonyms for "system.": Process, protocol, machine, machinery, mechanism, and mechanics. I'll also point out here that some systems are visible (mechanical, touchable), while others are invisible (communication protocols for instance).

> "If you could see the individual systems of your life from moment to moment, would you assertively work to manage them so they produce the personal control you want?, Is it somehow altruistic to allow chaos to reign?"

The key to effectively managing your life is a straightforward view or systemic perception that only requires a tweak in how you are currently perceiving your world in order to achieve the machinery results you want to happen in reality. Make this elementary adjustment in how you see things and you will be able to determine your life's results, you'll watch each day unfold as a graceful, exhilarating dance of a mechanical precision. You'll discover that the magic you've been seeking all along is in life, just as it is at its greatest.

If you finally see systems relentlessly working at their art as they currently are — the random yet predictable machinery that has been producing some apparently random results— do you want to take the complete control of that machinery in order to achieve your main goals? Would you direct, create, delete, modify, and adjust those machines to produce exactly what you want with a bit of will and control, or would you rather just turn your back and quietly let the machinery run the same old random results?

> **“Does this make sense so far? If so, read the manual and use the machinery.”**

Travel through these pages with me and read without the influences of peer pressure, religious dogma, political incantation, family dictate, and/or any other assumptions you could have falsely internalized along the way. In the now, temporarily set aside the menu. You can pick it up again later, but for now, to accomplish this take control transformation, go a layer higher and rely on the critical thinking principles you should already have assimilated and internalized. Let’s go to your core, to explore how things work.

And remember that no one out there is monitoring what you think or believe. This is because they’re too busy coping with their own personal challenges.

Control is what you want

> “Being a control freak is to be avoided at all costs; Isn’t this culture’s incessant search for control over what is not you or does not belong to you the root problem cause?”

Some people cripple themselves because of a certain brand of political correctness, and it revolves around the obsessive misinterpretation of the word “control.” This is not a problem for you but it may be a problem for others which you can avoid in order to help them only if you want.

For each of us, this control-seeking can be problematic without the proper understanding reading materials are solving with the proper focusing that goes with it. The seek and commitment to clarity started with our first breath, and it won’t end until our last. The opposite of having the full control is to be out of control, and it’s the out-of-control parts of our lives and the lack of a proper comprehension that cause pain. Is being out of control a good thing? Everyone seeks the opposite which is to have control and a proper clarity of understanding ensuring good skills of processing information.

It’s ironic, but a rejection of control-seeking is, in itself, an assertion of control.

Within your circle, you can manage the development of a particular skill and then, in practicing it, the skill will become more honed, more complex, more controlled. How about making more money, finding new friends, or getting fit? It’s the same thing as you act within your circle: Get good at what you do. As you improve your expertise in a particular area, pay attention to feedback, tweak incessantly, and become more efficient at creating value for others, and getting ahead will happen almost spontaneously. Becoming adept at anything has everything to do with gaining more control.

The consequence? Getting efficient inside your circle of influence is how the circle gets larger. The selfish/greed element is always out there, but even that is not about money or the lack of it. It's about control. So your best bet is to seek for knowledge and understanding, it will then brings you a tremendous wisdom and power that goes with respect and honesty.

Sometimes it's breaking off a relationship or doing what is necessary to begin a new one. Other times it's making business deals, and all the time it includes routine inside-the-circle mechanical work: eating right, exercising, finding enough sleep, fulfilling responsibilities, and treating other people with respect, love, and fairness.

As an example, let's talk about control within a family. This is what works: The parent and the child are not pals. The parent is the parent, and the child is the child. The parent acts like a parent and exerts respectful control over the child. The mechanical reality is that the parent must ultimately direct things if family life is to stay orderly and constructive, and the child can develop a spine and learn to respect others. The posture assumes the child will be a parent one day, too, in control and responsible for preparing yet another child to be an adult.

> "If I look at things in this way, it seems my marriage is a battle for control.
> What can I do?"

Here's a concept that's central to the systems mindset vision. Get "outside and slightly elevated" of the particular situation. Together, both of you take a position where you look down on this thing called the marriage relationship. Never mind the individual personalities and consider the relationship as a separate closed system: two people in a pact with certain needs, expectations, and goals. This is the external perspective in which the linear, mechanical dynamics of a system can be analyzed without a power struggle ensuing.

Ask, what are the unemotional, mechanical rules of this marriage? Get specific about the details. For instance, when exactly is my time mine, and your time yours? How, precisely, is the money to be spent? Who earns the money? Who manages it? What are our promises to each other — clearly defined promises that have to be kept to preserve trust and the marriage itself?

Eckhart Tolle talks about this "outside" concept in the first pages of his book *The Power of Now*. In his dark days, there came a moment when he said to himself, "I can't live with myself anymore!" In that observation in which he was involuntarily thrust outside of his own self and was able to look down on his existence, he discovered, "There are two of me, the watcher and the watched."

How profound, as he realized for the first time that there were two of him, and that through his new outside positioning he could choose which one would be in control! He then acted upon this simple insight by assertively managing himself, and then he built a life of contribution.

So with your partner, see the marriage as the independent mechanism that it is. To negotiate a relationship in this way is refreshing and exciting.

> “How is a health problem related to control?”

In any instance of illness or injury there is some degree of anxiety caused by the decrease in normal functionality. A virulent strain of cancer is perhaps the most vivid illustration of this, whereby the ultimate loss of control, death, is a real possibility.

> “What about work? I’m a manager and can’t get control of my staff. I can’t convince them to do things the way I want them to be done.”

Your business department is your responsibility, so it’s within your circle. It’s your machine, your primary system. And this primary system is made up of sub-systems. And yes, you can consider your staff — and your own self — as sub-systems within this primary system that is your department or your own little sandbox .

You want to be outside-and-slightly-elevated as you see them and yourself functioning down there like an ecosystem such as a stable forest and a vivid jungle. Within a business, a vital step in applying the systems mindset effectively is to ask staff to list, in black and white, the precise sequential steps of the execution of their various work processes.

Then, ask them what they think and how they would go about performing their duties. If their recommendations are sensible, you implement them. Then, turn your people loose, giving them support, the tools they need, and rewards when they achieve what you want them to achieve. Do this, and the cooperation you seek will enter through the side door, with enthusiastic employees willing to give 100%, because they are part of the decision-making process and are being properly compensated for their good work.

> “Personal control and design of systems is a good thing.
> You probably may want as much of it as you can get.”

A collections of separate systems

There must be some quiet, careful observation that is outside of any menu-driven belief system. This doesn’t mean the belief system has to disappear; it means that for a short while it is set aside so there can be an unbiased examination of how things are going on behind the hood.

Now it’s time for some careful and quiet observation.

Look around: in your home, on the street, or at work. Let’s start with your car, a primary system, which, like any system, is intended to accomplish a task. In this case, the task of your car is to provide you the means for you to travel from point A to point B. And like any system, your car is a collection of interconnected sub-systems.

What does the radio have to do with the brakes? What does the cleaning or good treatment of your car have to do with the driving experience? Or in what way does the transmission affect the air conditioner? And what is the involvement of the headlights with the speedometer?

In each pairing, there is a relationship or not. And what about the primary system that is your body? What does your liver have to do with your stomach and what does your pancreas have to do with your brain? What have to do quality food, calm, love, passion with your life? Or, what does your left foot have to do with your right hand? Again, in each matching, nothing or something important!

Yes, using your car like using your body is, in fact, using the sub-systems that are relative to their primary system, and some sub-systems are connected to each other and work together to the benefit of the primary system, but in their essence, the sub-systems are independent entities.

> "Your life is a collection of individual systems!"

Do you want more evidence? Quietly observe your everyday world. At home, you cook a meal. How is that process associated with washing clothes or watching TV or sleeping? And at work, what is the connection between making a sales presentation and preparing the payroll?

Back to your car: The auto mechanic isolates a problem to a particular subsystem and then corrects that problem in that malfunctioning subsystem. Presuming you're dealing with an honest mechanic, if your alternator has failed, that mechanic will correctly solve the problem of that sub-systems, just like you are able to do with your own body and habits.

And with your body, if you have a broken leg you won't be rushed to a dermatologist. You're going to be seeing an orthopaedic specialist. This separate-system reality is ubiquitous. Your whole existence and all the world around you is an immense collection of independent systems and sub-systems.

> "If you can internalize this fundamental principle, you'll have enormous advantage over those around you."

Acquiring this deep understanding is what I call "getting it," and after it happens your future actions will be super efficient, directed by this more accurate comprehension of mechanical reality.

The frenetic life

> “My life is hectic. Too often I feel confused and just can’t seem to get things done. If I back off and take a breath, I feel guilty. If I proceed, I make a mistake. Life is chaotic and I feel trapped. Is it me?”

Well, yes, it is you, but that’s a good thing because you can fix you. You are the supreme commander of you, and that means there is still and always a great margin for improvement, learning, and life’s new experiences to assimilate.

Because new visions can enable you to create new conditions of life, the first efforts are to forge the things you need in order to achieve that specific vision which can include to have more free time and enough money to take care of your dream and self and build something great. Realizing your projects and dreams should work with creating the proper environment for your family to be enjoyed by the present moment with your external beloved ones.

This is what I want for you: to experience the systems mindset insight and then create exactly the life of freedom and wealth and peace you’ve always wanted.

But let’s start by tackling the elephant in the living room, what may be your largest challenge in acquiring the systems mindset. Although this particular elephant isn’t the subject of the book, it’s the reason most people can’t even get started in the process of securing the personal control they need to effectively manage their lives. It’s the plague of what I call DDD: Digital Drug Dementia, the mental-paralysis epidemic that is ignored even though, or maybe because, most people are infected. It’s the primary reason for personal flakiness. (Flaky people are everywhere. Have you noticed?) DDD is the reason most people can’t concentrate, and concentration is mandatory if there is to be action one layer deeper: down in that place where life results are created. DDD detracts from every facet of a life and makes it impossible to break free, so let’s see if it’s a problem for you. (If it is a problem and you’re not willing to deal with it, then no matter what you learn here, getting a grip on things is going to be tough.)

> “OK. I admit it. I’m a bit flaky. How did I get this way? Just how big a problem is it?”

I should qualify this. It’s OK if you’re a little flaky because, for good reason, a tendency in that direction is part of the human condition. Thoughts race through our heads in a sequence that is not always logical, but this rapid thought fluidity, fostered over eons, gives us quick adaptability to the rushing torrent of the world. This wonderful ability to adapt is why we humans are at the top of the food chain. Our experience varies moment to moment, and we adjust quickly to the ever-changing stimulus: first we try this, then we try that, and then we go in yet another direction to see what happens next. We’re experts at instantly adjusting to circumstance: listening, talking, thinking, analyzing, testing, seizing opportunity, changing our minds, learning, and taking action right now due to the new information that just popped up.

It’s the human gift that our brains are fluid and able to move fast, so don’t waste mental energy thinking it’s an internal dysfunction and tune the environment as to your advantage so you can have the conditions you require to not be always drawn in energy and really get nerves to do it.

But this incredible agility — our innate capacity to turn on a dime — is also an open door for the DDD elephant to charge into the living room and take up residence, paralysing our ability to focus.

What is the digital component of the DDD plague? It began sixty years ago as TV made its debut and our culture first met the screen. It’s the media we absorb; it’s the devices we respond to throughout the day, our attention fitting from one thing to the next. We’re moving fast, fast, fast! It’s the steady onslaught of email and social media: Texting! Twitter!

Facebook! And it’s the passive entertainment, too, including TV, movies, and portable music devices with their infernal earbuds that lock us in our cages no matter what else we might be doing.

There’s online gaming, too. It goes on and on . . .

Bam! Bam! Bam! We lurch from one topic to another hundreds of times — thousands of times — each day, and a lot of us have become quite good at it. And in all of this we don’t get much practice concentrating. Truth is, we learn how not to concentrate, becoming experts at shallow-thinking multitasking.

And we get impatient with ourselves and with others, wanting answers now!

Look around at any cluster of people and see how many are mentally extracted from the real-time events of the moment, hammering away on a smartphone or plugged into music.

It’s not just that our concentration abilities have been crippled in this focus-hostile world. As we’re swallowed up by our devices, we don’t think creatively. Why? Because we don’t need to. Information is ceaselessly delivered to us, and for a huge swath of humanity it’s not necessary to think originally, so it doesn’t happen much. Instead, we absorb, with even further attention span diminished. You know it’s true.

How things happen

In your kitchen, your toaster is a system. After a couple of minutes of operation, the toaster’s result is a slightly charred slice of bread if you care to manage it properly.

From the TV system, you're delivered precise, clear and unbiased quality information and entertainment over various periods of time. The system of the hand at the end of your wrist gives you a multitude of results all having to do with the physical manipulation or usage of external objects as you prefer — each instance of which takes some amount of time to accomplish.

Most people don't see the systems of their lives so they don't manage them, and unmanaged systems produce random results. You don't want random results! It's a numbers game, and indiscriminate results will not often be congruent with your goals. You want the exact outcomes you desire.

How about your high school education that led up to your diploma? What was the process necessary to get the diploma? Did you go through four years of public or private high school? Or, over some duration of time, were you home-schooled?

There is no disputing that each result of your life came about because of a series of steps that executed over a period of time. This is how things happen!

OK, because the creator made that happen and we should just conjure up a smile and go with the flow. I viscerally disagree. Yes, every "thing" does happen for a reason, but the reason for each of those things is the linear system that preceded and then produced it.

Is God involved? I'm certain of it. But the universal law's gift to us is not a preordained future or a series of divine blessings we've earned through prayer, good deeds, or deep faith. God's gift is bigger than that. It's that every one of us has been granted the power to choose and act, to adjust the mechanical elements of our lives to make things better.

The question is, do we put that power to good use?

> Achieve success, stop trying to rearrange the bad results of unseen and therefore unmanaged systems. That's fire-killing. Instead, see and then manage your machinery so it produces the results you desire."

There's nothing airy-fairy here. It's all mechanical.

It's an outright acknowledgement of the miracle of the everyday sights, sounds, and events of your life! The machinery was always there, working away. You just didn't see it until now.

The moment you acquire the systems mindset, your faith in how the machinery of your life operates will be as strong as your certainty that gravity holds you to the earth. Once you see the machinery, getting what you want in your life is a simple thing.

99.9% of everything works just fine

> "This all seems great for my own situation, but there is so much wrong in the world! What about that?"

Right now, no matter where you are, look around. Can't you see the perfection? The world has been executing just as it should have been in each and every moment of your life. Yet you can use your thinking to identify how to use it to your advantage since it is the only think you can do, and once you can be efficient and confident there is a lot of thing you can do about the world.

If you're inside your house or apartment, what do you observe? In the kitchen, is the water coming out of the tap when you turn the knob? Is the heating or air-conditioning working? Is your TV turning on? What about the electricity? How about your smartphone? And your heart? Is it beating? What about your brain? Is it thinking? Is there oxygen in the air?

> "Can you breathe deeply, contemplating the stars?"

The idea that the things of the world are good is a revelation to nearly everyone. Why? Much of it has to do with the media, which does everything possible to seize our attention. Simply put: Good news doesn't sell, so we're delivered the morbid, which is invariably more interesting.

> "Truth is, what is presented to us in the media is a rooted-out tiny slice of what isn't OK, and it's a profound miscalculation to generalize about the world's condition from that anecdotal evidence, anecdotal evidence propagated by people with an agenda."

Unless you live in a part of the world that is a hotbed of dysfunction, your life is probably pretty good. Think of the people you've seen who are physically attractive and healthy and who have lots of money, power, fame, and a future full of possibilities, but are miserable. Their worlds are, in the mechanical sense, near perfect, but their states of mind stink! Do not equate your immediate negative emotional state with the condition of the world.

Because the elements of a system execute according to their own construction to produce a result, you have incredible power if you stay within your circle to work on your own systems, the systems you can actually affect. This is where you can make things better. Don't beat your head against the wall trying to adjust things outside your circle.

> "That system is working perfectly according to its construction. If you want a different result from a system, you must go inside it and adjust its configuration."

There's no question that the human negative aspects of fear, ego, greed, etc. are the root cause of the interferences. But still, those interferences don't negate the fact that the systems of the world are dependable, propelled by an invisible force that not only pushes them toward completion of missions, but also relentlessly works to repair any damage.

> “Get your machinery pointed in the right direction and operating efficiently.”

The past is gone, but value it in a peripheral way for two obvious reasons. First, some of it might emerge in some way to affect your current decisions. But don’t regret the past or wallow in it. It simply doesn’t exist, and for that matter neither does the future.

There’s not that much to fix

Briefly, let’s cover this important point again: My proposition that the world is operating almost flawlessly is in the statistics, that by tallying the numbers you can see that we live in a remarkable world.

No matter the problems, 99.9% of the sub-systems of the world, including your world, are executing perfectly. And so, that means that if your life is problematic, there isn’t that much repair work to perform.

> “Find yourself eagerly discarding those few dysfunctional primary systems that have been dragging you down.”

Go into the relevant system to make an adjustment so the problem never occurs again. This is why we don’t have many problems! But that’s a business. Private life can be simpler than business life, but problems can sometimes be more difficult to repair—family relationships in particular. Within a business there are formal and informal codes of communication and responsibility, and there’s a chain of command in which an ongoing problem in a relationship can be solved by the departure of one of the individuals in the relationship. Removal of one party or the other is not so easy in a family! So, my condolences if you are faced with a family member who refuses to take a businesslike, systematic, “outside and slightly above” approach to solving a bad situation, and who is not going to be leaving. At least, know that you’re not alone: There’s a lot of family dysfunction out there.

The bonus is, of course, that the amount of fire-killing in your life will continuously decline until it almost never occurs. Here’s what happens: Your net amount of time spent killing fires will decrease, while your net free time will increase, and one way or another, this incredible efficiency will positively impact your personal financial bottom line. And this wonderful snowballing scenario doesn’t end at some point. It continues on and on: As time goes by, everything gets better. In discovering the perfection of the systems of your world, you may ask many questions as life goes on.

> “The universe is perfect, the 0.1% is about what you, as a living system, can improve using the smartest way possible.”
> — The universe

Your task is to create value

Good for you to ask that kind of question. It shows you understand that the world functions in a formulaic way, that there are principles that work everywhere and all the time.

Without getting all woo-woo, here's something you can keep in mind: Personal freedom — meaning, among other things, lots of money and spare time — is a direct result of creating value for others. You can describe it as Karma or the Golden Rule, but in any case it has to do with addressing a mechanical reality of life here on planet earth which is about social organization and humans norms: If you want to get ahead, no matter how efficient you are, you must deliver value to others. In a free enterprise economy, you must do enough for someone else that they will want to pay you. In your job, when you go beyond the expected requirements, you'll find yourself moving up the corporate ladder.

In your romantic relationship, improve your partner's everyday existence, and he or she will feel good about doing the same for you.

Begin at the bottom

Imagine a V as a representation of your life's progression through time. There at the bottom, nestled at the apex, is your core belief about how the world functions. Your life proceeds upward and outward from that singular point. Represented by the two expanding upward legs, your actions determine how your life unfolds, and all of your actions start with that fundamental belief, down there at the bottom of the V. So, before proceeding let's identify your deepest belief about reality. What is your most unshakable conviction? As an example, here's mine. More than anything else I believe the mechanisms of the world execute over time in a linear sequence: One step leads to the next step, and that step leads to the next step, etc., until the end of the process when a result is produced. This is my deepest belief of fundamental physicality. It's at the bottom of my V, and no one can change my mind about it. So, deep down, what do you believe about how the world works? What do you think about order and disorder?

Consider this: Presuming your fingers are working normally, could you, in this moment, wiggle your fingers? How certain are you that you can do this? Do it now. Did your fingers wiggle? Are you surprised they did? Of course you're not surprised. This degree of certainty is what you feel about whatever conviction lies at the bottom of your V.

It's what you absolutely believe about physicality in your deepest gut. The V analogy stands on its own as your mental cornerstone of what you don't question, and you will identify and then build from this unshakable certainty. In all probability, this certainty will complement, not replace, the rest of your belief system.

Will this conviction empower you? Will it be congruent and contribute to your new posture of taking charge of your life? I hope so. If not, will you re-examine how you see things? In any case, it's important that you identify this core assumption now, before we go further.

> "As you begin seeing things differently, you'll find your life becomes fascinating. Your misconception of a world of confusion will be gone forever."

Systemic mindset analogy

> "Going with the flow will ruin your life.
> Learn, resume, plan, trust, delegate, go ahead, and put your passion at work."

When your former my-world-is-chaos mindset resurfaces and begins to drag you down, rescue yourself with a real-world analogy. When you get distracted, it will pull you back up to your new, much more productive vantage point. Do you believe that sound comes from your throat when you talk? Can you doubt the existence of the tree that stands in the backyard? Is there any question that there are toes on your feet? And speaking of your feet, my bet is that you are totally confident that, right now, you can tie your shoes. My point is that, to give power to your analogy, it should describe a physical reality that is indisputable. You want your analogy to be gut-level believable.

This analogy bolsters the strength of the systems mindset posture and suggests the level of attention you should give to every recurring system of your life: to see each as a separate entity, take it apart and examine the sub-systems that compose it, and then make improvements on those sub-systems along with designing the systems you need in order to produce the results that you want the system to perform to achieve your personal objectives and projects.

Automate and delegate

Use the title of this chapter as the filter for many of the decisions you make, especially at work.

If you're going to quickly get out of the middle of things and gain a truckload of personal control, you must be sure you're headed in a single direction, not helter-skelter, all over the place. It really does boil down to picking the correct road and then traveling down it efficiently, and a great way to assist that effort is to pass every decision through this "task filter."

To reinforce the concept's validity, think about the opposite tactic: doing every task manually or doing them all yourself, or accepting every burden that shows up on your doorstep. And yes, it's especially about work, but it's also about relationships and health.

Automating and delegating can be combined. For example, the strength coach at the gym, John, guides you through your twenty-minute high-intensity training session. The automating part is simple: You just need to show up as scheduled. The delegating part is giving control to John.

There's one other thing. Know that you already delegate and automate all day long. Truth is, although you don't know it, you're really, really good at it. As an example, I'm going to give you a systems mindset vision that you will not be able to shake. Be forewarned that it will embed itself in your head. It has to do with a daily ritual that you've taken for granted up until now. Here it is: In the morning after you wake up, shower, dry yourself off, hang up the wet towel, get dressed, and then go about your day's activities — have you ever thought back about that wet towel, hung up and drying, back there in your bathroom, requiring zero attention or additional input from you?

Deals killers and the main machine

You're a primary system, an enclosed entity made up of numerous spinning wheels, all contributing to the singular purpose of that entity, this is, to accomplish a goal.

The main machine is you. You're precisely engineered, perfectly equipped to choose objectives and then adjust your output in order to reach them.

And whatever your goals might be, of course it makes sense to drop any behavior that hinders their attainment. This chapter is about deal killers: the things you might be doing or might not be doing that could erase the accomplishments you've managed to secure (or are about to secure). I also list some routines for maintaining and strengthening your "main machine."

First, there's chemical addiction. If you have one, you must find a way to defeat it. There is help out there, and a quick Google search will tell you where to find it.

And, second, there's sleep deprivation. How boring to hear yet again that most of us don't get enough sleep. But it's true. The human body requires a certain amount of sleep in each twenty-four-hour cycle.

Getting enough of it is not something you do only when you have the time. It has to happen or things will go bad. And please don't be one of those people who wears their sleep deficiency as a badge of courage.

Third, coddle and challenge your physical body, your "main machine." It's the ultimate primary system of your existence — the vehicle that carries you around — your special endowment. Incredibly complex, it wants to perform well for you, so do what you have to do to keep it strong and resilient.

Taking proper care of the body is a moment-to-moment quest. Following are details of my personal stay-well master system. The commonality among the various segments is that they are all “mandatory preventive maintenance” efforts, the moves I have to make whether I want to make those moves or not.

List what kind of actions does humans or any other biological systems can perform on their sub-systems in order to regulate themselves and so positively impact their performances. Try to see the relations between ineffective system management and effective steering governance on a greater organism such as a team or a legal organization.

The fabric of your life

The world is a vast collection of individual systems. In acknowledging that, could it be that the common presumption that the world is not functioning well—that the world is a mess—is wrong?

Yes, that presumption is wrong, because on any given day, 99.9 percent of life’s systems work perfectly. Consider the countless processes that execute with amazing efficiency: plants, animals, oceans, businesses, airplanes, bicycles, cities, whole societies, and six billion human bodies. We don’t notice the exquisitely performing systems that make up our existences, so we take them for granted, never appreciating the impeccability.

Yes, there is pain in the world, but as we hyper-focus on these personal, mechanical, and geopolitical systems that are not to our liking, we get swallowed up and conclude that perfection is the anomaly, imperfection the norm.

> “This perception is more than narrow. It’s exactly backward.”

If you perceive the world as chaotic, your life will be chaotic. The reason for this is not because you have a bad attitude. It’s purely mechanical:

> “If you want a machine to produce a particular end-product and you manage that machine as if it operates in a certain way, but in reality it operates in a different way, how could that machine possibly produce the end-product you want? It’s as if you tried to play baseball using the rules of football: There will be chaos.”

As we’ve discussed, for some mysterious reason, systems want to execute perfectly, and for your personal situation you can count on an overwhelming bias toward efficiency, rather than chaos. And if your world isn’t to your liking in this moment, it won’t take long to get things straightened out.

If an outcome is not what you want it to be, it doesn’t mean the system that produced that outcome is fawned. In fact, barring outside interference, that system is performing exactly as it was constructed. And so this life you live is composed of a countless number of perfect linear systems, many of which are under your control. These systems are the invisible threads that hold the fabric of your life together. If there is an outcome that doesn't suit you, you can change that outcome by making an improvement within a system, adding a system, or eliminating a system. In the typical life's rejuvenation, it's "all of the above."

> "And again, what of those things you can't fix because they are out of your control? Relax and move on."

If you can't adjust something, don't worry about it. Metaphorically speaking, if you don't like the TV program, change the channel or turn off the set. You are not at the mercy of mysterious conspiring forces or the swirling backwash of chaos! Stop fire-killing and expend your time and energy on incremental system-improvement efforts that will deliver the life results you want.

About systems

Systems philosophy

A mechanistic world

The Western World as we see it today has been greatly influenced by the Industrial Revolution. The European Renaissance inspired that revolution, partly through the work of René Descartes, the French philosopher of cogito ergo sum fame. His name is enshrined in Cartesian Reductionism, his philosophy of breaking down big things into ever-smaller, and hence more understandable, pieces before assembly or reassembly into something larger. Cartesian Reductionism is alive and well today in almost every walk of life. Every time we list, prioritize, disassemble, disaggregate, decompose, etc., we pay implicit homage to Descartes.

Perceived limitations

In the 1930s and before, it was becoming apparent that reductionism and mechanistic views of the world were limited. Initially, the main issue was Life. Life seemed to confound the traditional sciences, physics and chemistry. Organisms could clearly be alive, decaying or dead. Detailed physical or chemical examination, however, observed no difference between those states. DNA, for instance, is precisely the same whether the organism, for which it acts as template, is alive or has been dead for millions of years. Life also represented organization, yet physicists believed implicitly that order should decrease in any closed system over time.

Things other than living organisms were also displaying characteristics that were inconsistent with a simple mechanistic viewpoint. Stability in physics is associated with a rest state of low energy. A bus, for instance, is stable when forces restore its centre of gravity to its lowest point, minimizing potential energy.

Like organisms, mass production systems stabilize at high energy with parts entering, being assembled and finally ejected, to be sold in the market place. As long as the mass of parts entering is roughly equal to the mass of things leaving, and so long as energy was being expended to assemble and move the parts internally, the whole is evidently stable, yet at a high-energy state, not low.

Analogies were presenting themselves between organisms on the one hand and organizations and civilizations on the other. This is the so-called "organismic analogy," which upset some historians, highlighted similarities in behaviour and composition between organisms and large-scale human activity systems. This was not to suggest that civilizations were organisms, but that each constituted a reduction in entropy, each had a life cycle, with growth, stability and finally death; often sudden death; and each appeared to have essential internal structure with organizational parts contributing to the viability of the whole.

It had been the practice to compare the various parts of the human body to supposed mechanical equivalents. The heart was a pump, made of muscle and tissue to be sure, but essentially just like a mechanical pump. The kidneys were filters. The eyes were cameras. The brain was a computer. And so on. Looking at the human body in this way, on a piecemeal basis, it seemed apparent to the observer that there was nothing really inexplicable about life. Man was little different from the robot of science fiction, or the automaton of the ballet. Earlier, it was Descartes himself who introduced the notion of the animal as machine.

The animal was complex clockwork.

Later, the idea emerged that man was a heat engine, then a cybernetic machine, then a molecular machine. Such ideas face problems. Ludwig von Bertalanffy identified three:

1. **The origin of the machine:** Descartes relied on creation by a blind watchmaker, but how do machines come about in a universe of undirected physiochemical events? Clocks do not create themselves in Nature.
2. **The problem of regulation.** Machines can regulate themselves, of course. The problem concerns regulation and repair after arbitrary disturbance. Can an embryo or a brain be programmed for regulation after disturbances of an indefinite, possibly immense, number?
3. **The continuous exchange of components.** Metabolism is a basic characteristic of living things. Life is a machine composed of fuel spending itself continually, yet maintaining itself. This creates a paradox. A machinelike structure of the organism cannot be the ultimate reason for the order of life processes because the machine itself is maintained in an ordered flow of processes. The order, then, must lie in the overall process itself.

Life and the second law

The second law of thermodynamics dictates that entropy will increase with time in a closed system. Life appeared to confound the Second Law, the physicists' touchstone. Towards the end of life, when decay set in, it seemed that the second law regained lost ground.

At one level, the solution to this issue was evident: organisms could ingest food, and use the ordered substances to maintain and build their structures. In other words, an organism could feed on negative entropy, i.e., food, and so decrease or hold steady its overall entropy. This did not confound the second law that, after all, referred to closed systems, since an organism that could ingest was clearly an open system. It was becoming apparent that all systems were open, and that, in consequence, the second law may prove difficult to apply rigorously on any scale smaller than that of the universe itself.

Information and entropy

Entropy is a measure of disorder. Information theory shows that information reduces uncertainty in the receiver, and hence reduces entropy. Information cannot be readily related to energy, but it can to entropy. If we are trying to choose between 8 options, and we receive information that identifies the best choice, that information has reduced our uncertainty eightfold, or the amount of information is $\log_2 8 = 3$ bits (binary digits).

Another form of information is feedback. The primary regulation in organisms is derived from dynamic interactions, generally between two substances, muscles, etc. Increasing blood sugar level is regulated by generation of insulin. Embryonic bud growth is directed by the creation of chemical gradients. And so on. Feedback mechanisms within the body are secondary forms of regulation, such as maintenance of body temperature. Dynamics are at the heart of regulation in organisms, rather than control by feedback.

Causality and teleology

In the mechanistic world view, the goal of science was analysis, the breaking down of phenomena into ever-smaller parts and the isolation of individual causal factors. Organisms were split into cells, processes into activities, behaviour into reflexes, mass into atoms, etc. Causality was unidirectional. One gene corresponded to one deficiency in the organism. One bacterium caused one disease.

This idea of individual units acting on their own in one-way causality proved insufficient to explain observed phenomena. It became necessary to consider groups of parts mutually interacting. The need for a holistic viewpoint, to consider wholes, to be organismic, for gestalt, emerged. It was proving necessary in many fields of scientific endeavour to consider systems of elements in mutual interaction.

In a similar vein, the mechanistic world view had difficulties with ideas of directed behaviour, or teleology. Analysis down to individual isolated components erases all trace of directed, adaptive, or goal-seeking behaviour, which was therefore viewed as mysterious and beyond the realm of scientific research. Yet the evidence of teleology, of purpose and of goal-seeking behaviour in organisms, was unmistakable.

Organization was also inaccessible to mechanistic science. Organization of people or of organisms is concerned with growth, hierarchy, structure, dominance and submission, control, etc., none of which appeared in traditional physics.

Concept of open systems

The concept of the open system emerged in response to many of the shortcomings of the mechanistic viewpoint. An open system exchanges energy, material and information with its environment. In modern biology, the open system is fundamental. The human body is an open system, as are many of its internal organic sub-systems. Human activity systems, organizations, and many technological systems are open systems. Some systems may be considered more open than others, but all systems must be open in some degree, otherwise we would not be aware of their existence.

The basis of the open system model is the dynamic interactions of its components. In this it is differentiated from the cybernetic model (q.v.), which is based on feedback. The open system ingests, and removes waste. The open system responds to stimuli. The open system can exhibit growth, can be stable at high energy levels, and can collapse and disintegrate. The open system can maintain and (may be able to) reproduce itself. The theory of open systems is part of general systems theory.

Summary

Systems philosophy has emerged as a reaction to the limitations evident in the philosophy of Cartesian reductionism in a mechanistic world. The most evident limitations include the inability to distinguish living from the non-living parts, and to address the ability of life to decrease entropy in apparent contradiction of the second law of thermodynamics.

Observing the behaviour of whole systems, and seeing the parallels between different systems, enabled system philosophers to perceive a reduction in complexity. A "systems view" made complex things and situations simpler to understand, organize and manage.

An "organismic analogy" was observed, in which organizations behaved like organisms, and civilizations were observed to have life cycles analogous to those of organisms. This was not to say that organizations were organisms, but that they behaved in many ways as organisms behaved, and in particular that they were made of many complementary parts mutually cooperating to create the whole system.

The notion of the open system was developed, a system in which there were inflows and outflows, and in which stability occurred at high energy, not low as with physical entities. Many real world systems were recognized as open systems, including socio-technical systems, social systems, industrial process systems, etc.

General systems theory described open systems and their behaviour mathematically, and using models. These models in particular influenced the fledgling disciplines of operational analysis, systems thinking and systems engineering. It became practicable to define and identify open systems, and to categorize different open systems according to their shape, structure, purpose, etc., without necessarily identifying their content in any detail.

Instead of looking inside a system, it was possible to identify its emergent properties, capabilities and behaviours. These emerged from the system parts, but also from the interactions between those parts. The notion of emergence became central to systems philosophy, systems science and systems engineering, together with three tenets: holistic, concerned with wholes; synthetic, built up from parts to create a coherent whole; and organismic, built up from complementary parts which interact to support each other and to create emergent properties, capabilities and behaviours.

Applied science

Classic science employs Cartesian reductionism, the breaking down of complexes into discrete parts; the parts, it is hoped, will be much easier to understand. The whole can then be explained by putting together the explanations for the parts.

There is a flaw in this reasoning, one that becomes more important as the subject becomes more complex. In breaking down a complex, the interconnections between the parts are themselves broken and lost. This is analogous to a surgeon excising the organs from a patient, examining and understanding how each organ works individually, and then putting them all back together again. The patient is, of course, long dead, and will not magically come alive again. Why not? Well, each of the organs remains healthy within the body by virtue of its interactions with all the other organs. Each and every organ depends on the other organs. Without those interactions, organs degenerate. Moreover, the organs are complementary — they each provide what the others need — and there is therefore, a minimum number and variety of organs for the body to sustain.

This mutual interdependence is the hallmark, not only of the human body, but of all complex systems. An effective national governmental system operates and behaves in just the same manner, for instance.

From a different perspective, it has become apparent that some "things" can exist only as wholes. Naval task force, for instance, would be ineffective if all of the major elements were not simultaneously present and operative, allowing the conduct of warfare on all three fronts: air, surface and subsurface. Effectiveness "emerges" from the dynamic interactions of the various force elements, not just with themselves, but also with some supposed foe. This notion can be generalized; effectiveness is the effect that one system has when interacting purposefully with another. It is, therefore, a function not only of the acting system but also of the system that reacts/is acted upon, and in consequence effectiveness is a dynamic parameter, shifting with time during the course of interactions.

This is not a perspective with which reductionists are comfortable.

Although reductionist philosophy has been very successful, then, it misses something. It misses the interactions between the parts of a whole that give that whole unique properties. It is the interactions between our organs that keep us alive. It is the interactions between the neurons in our brain that keep us conscious.

Consciousness is sometimes referred to as an emergent property.

The term, emergent property, refers to properties of some whole that are not exclusively attributable to any of its parts. The pungent odour of ammonia when two colourless, odourless gases, nitrogen and hydrogen, combine. The appearance of smooth movement when a series of still pictures of a moving subject are flipped in sequence. The high reliability of a piece of equipment made from many unreliable parts. And so on.

Emergence originates in the interactions between the parts.

> **“Reductionism obscures those interactions, and therefore denies emergence.”**

What defines a system?

Trickier than you might think. According to *chambers dictionary*, a system is:

> "Anything formed of parts placed together or adjusted into a regular and connected whole; a set of things considered as a connected whole;" and so on...

Chambers is OK as far as it goes, but it overlooks interactions between the parts, and it omits mention of emergence, Then there is a definition by the *INCOSE Fellows*:

> "A system is a construct or collection of different elements that together produce results not obtainable by the elements alone. The elements, or parts, can include people, hardware, software, facilities, policies, and documents; that is, all things

> required to produce systems-level results. The results include system level qualities, properties, characteristics, functions, behaviour and performance. The value added by the system as a whole, beyond that contributed independently by the parts, is primarily created by the relationship among the parts; that is, how they are interconnected (Rechtin, 2000)."

This is much better — it is getting to the heart of the notion of "system," although it is studiously avoiding using the term “emergence,” preferring instead to refer to "systems level." It falls down in the last sentence: it is not the relationship among the parts that "adds value" — but rather the interactions between the parts that cause the system to be more — or less — than the sum of its parts. No interactions, no emergence, no "added value".

Relationship between the parts may be necessary, even inevitable, but it is not sufficient. Being related does not make someone "part of the family" — that requires continual interaction. Life is not sustained by the organs being related to each other — they have to interact, too. Apparent movement when flicking through a set of still photographs of a galloping horse derives from interactions between eye/retina, optic nerve and brain — that the parts are related is true, but not causal with respect to the emergent behaviour.

My own definition has taken many years and gone through many refinement trying always to simplify, but it seems to be there, or thereabouts — finally:

> **"A system is an open set of complementary, interacting parts, with properties, capabilities and behaviours of the set emerging both from the parts and from their interactions to synthesize a unified whole."**

This covers the full ground as follows:

- **Open:** the system can accept additions and losses, inflows and outflows.
- **Set:** a grouping of things that have something in common.
- **Complementary:** together, making up a whole.
- **Interacting:** acting with each other, i.e., essentially dynamic.
- **Parts:** entities, pieces of a whole, and sub-systems.
- **Properties:** tangible, usually physical, features such as mass, volume, shape, appearance, etc...
- **Capabilities:** upper limits to functional abilities.
- **Behaviours:** reactions to stimuli.
- **Of the set:** of the whole system.

- **Unified whole:** the various parts operate together as one — the whole.

Note: the interactions identified in the definition are not confined to those between the parts. Some of the parts may also interact with entities that are outside the system, and these "external" interactions may also affect whole system properties, capabilities and behaviours.

Tenets of systems philosophy

Three tenets of systems philosophy are worthy of serious note: the organismic analogy; holism, and synthesis.

1. The organismic analogy proposes, not that all complex systems are organisms, but rather that, like biological organisms, they behave as unified wholes. Each has a life-cycle, each exhibit growth, stability and death — often sudden, collapsing death.
2. Holism proposes that everything within a system is connected/related to — and affects — everything else, so there is mutual interdependence. Viewing, or even considering, parts on their own is irrational. Systems, and their problems have to be viewed as a whole. Holism observes the tendency of the natural world to create ”wholes”, and that a whole may be more than the sum of its parts...
3. Synthesis is the opposite of reduction. Synthesis proposes that the various parts of a complex system cannot exist/survive/operate/behave/even be considered in mutual isolation. A system comes into existence when the complementary parts are brought together. Each then depends for its very existence on interchanges with the other parts. In turn, this implies that open systems are/have to be active/dynamic.

Understanding emergence

From the start, in the early 1900s, the “systems movement” has concerned itself with emergence, i.e., with emergent properties, capabilities and behaviours. Scientists observed that the behaviour of some wholes could not be explained by looking at their parts — in separating some wholes into their rationally separable parts, something “got lost”. For biological wholes, this was pretty obvious: carving up a body into its various organs resulted in loss of life, and reconnecting all the organs failed to restore life.

At a more prosaic level, bringing together elements such as the alkali metal, sodium, and the greenish gas, chlorine — both harmful to human life — resulted in crystalline sodium chloride, common salt, which is essential to human life: the properties of common salt are emergent, since they are not to be found in its rationally separable elemental parts.

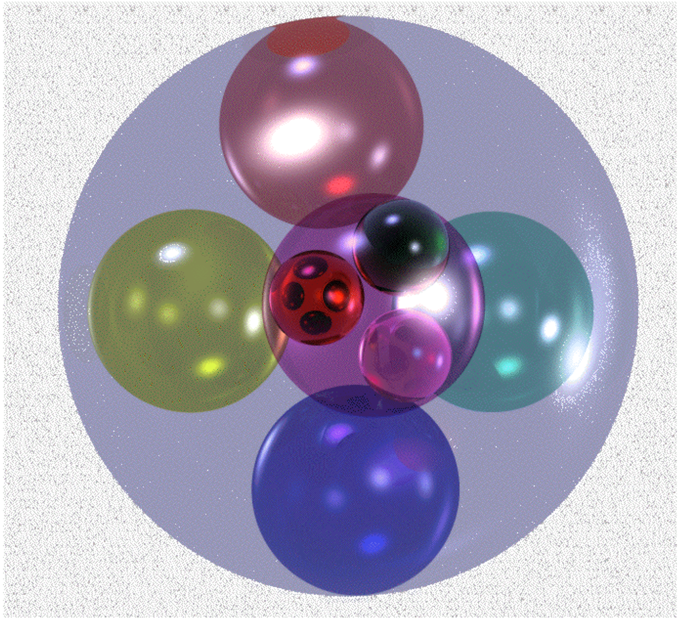
Not entirely dissimilarly, flicking through a sequence of still photographs of a galloping horse gave the impression of smooth movement. Where does this emergent property of movement come from?

Initially, emergence was seen as somewhat weird, even mystical and magical. Researchers, however, soon determined that emergence came about from interactions between the rationally separable parts of the whole, rather than from the parts unified… So, the outer electron pattern of the sodium chloride molecule, with outer shell electron interactions between sodium and chlorine components, gave it its distinct properties.

And the appearance of smooth motion emerged from the interactions between the still photographs, the continual bleaching/fading of the retina, the encoding of retinal data into some seven representations of each still image, the optic nerve, and the optical cortex, which was able to perceive smooth transitions — provided the stills were sequenced quickly enough — whence “what the butler saw” and, subsequently, the motion picture industry and today's television with its — typically — 50 Hz frame rate…

With developing understanding of the origins of emergence, it was only a matter of time before scientists began to ask: "Is it possible to select parts, bring them together, and cause them to interact such that specific/requisite emergent properties, capabilities and behaviours can be created?" And at that point, the idea of systems engineering might be said to have emerged. After all, there was a promise of being able to gain “something for nothing”, which is fundamentally tempting. Even more exciting, some things might be possible through created emergence that might otherwise be impossible…

Emergence and hierarchy



A classical view of systems is that they form a hierarchy of sub-systems within systems, sub-subsystems within sub-systems and so on ad infinitum. Looked at from the side, as it were, the hierarchy forms a pyramidal or conical shape. Looked at from “on top”, hierarchy can be perceived as a large sphere, with smaller interacting spheres within it, inside each of which are even smaller, interacting sub-spheres, and so on.

The graphic offers a notional image of systems within systems within systems.

Note that the outer blue system sphere constitutes a hierarchy level and that it will be interacting with other system spheres at that level, not shown. The first level of hierarchy down shows five large contained subsystem spheres, all presumed to be interacting through the contained environment. Each of these five large subsystem spheres has its own emergent properties. Interacting together, they constitute the emergent properties of the outer, containing system sphere. One of the large, contained systems shows three contained sub-subsystem spheres, also presumed to be interacting, and also exhibiting their own emergent properties.

Emergence is interesting from another perspective: the nature of emergent properties may be meaningless using the terms and language appropriate at lower levels of hierarchy. Peter Checkland put it this way.

> "The shape of an apple, although the result of processes which operate at the level of the cells, organelles, and organic molecules which comprise apple trees, and although, we hope, eventually explicable in terms of those processes, has no meaning at the lower level of description."

This is an important concept, particularly, for systems engineers to understand. The emergent properties, capabilities and behaviours of some system they seek to create will not be describable in the technological and engineering terms that they will use during the design and creating processes.

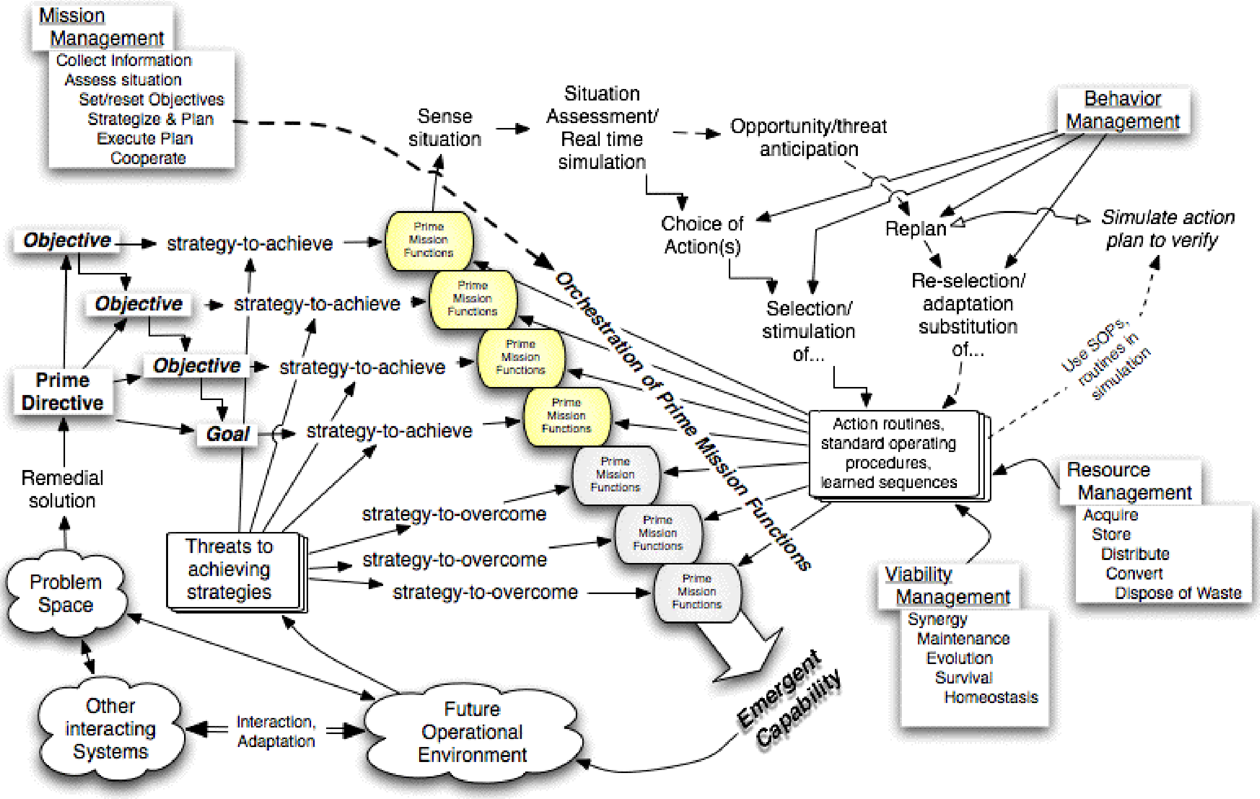
Designing and creating emergence

So, the essential idea behind systems engineering came to be: it should be possible to:

> "Select the right parts, bring them together, cause them to interact in the right way, and to so 'orchestrate' those interactions as to create requisite emergent properties, capabilities and behaviours."

In this way, systems, wholes, might be created that were “greater than the sum of their parts.” Rather than a largely mechanistic approach that had characterized hard science and engineering, this was founded in an organic metaphor, and would employ the systems approach. And, it was implicit that the kinds of system to be created would be open systems, acting and interacting with other open systems, and potentially adapting as a result of those interactions, in much the same way as organic systems are open, active, interactive and mutually adaptive. In other words, “of and about the dynamic real world,” rather than isolated in some closed, static environment.

It may not be immediately obvious how one might go about creating emergent capabilities in man-made systems. The following diagram, which is based on the systems methodology (q.v.) suggest one approach.



The figure draws upon the systems methodology presented in accompanying pages, and employs the **generic reference model** (GRM) — a general description of any open, dynamic, interactive system.

The systems methodology starts with the **problem space**, left, from which is derived a conceptual **remedial solution**. A **prime directive** (statement of ultimate purpose) for this conceptual remedy can be elaborated into **objectives** (sub-goals) and a **goal** (G), for which it may be possible to conceive **strategies** that the future system solution might employ to achieve.

These suggest in turn **prime mission functions** (PMFs) — the yellow lozenges — that the future system solution should be able to activate to manifest the corresponding strategies. In a similar vein, **the future system should be able to activate PMFs** — the grey lozenges — to address threats which it may encounter in its future operational life.

It is in the “orchestration” of these various PMFs, and their consequential interactions, that properties, capabilities and behaviours emerge in man-made systems. The orchestration — or should it be choreography? — of PMFs is shown diagrammatically in the right of the figure.

To understand how this might work, consider a seemingly-simple example:

- A young man is sitting on a bench beside a busy urban street, with traffic moving slowly in both directions.

- He decides to draw some money from the bank, which is some 75 yards up the road on the other side — this is his “mission”, and drawing the money is his “goal”.
- He stands up, moves diagonally towards the edge of the road, in the general direction of the bank.
- At the road's edge, he pauses, scans the traffic for a gap and decides to cross the road in two stages.
- He waits for a gap in the near-side traffic, and walks smoothly and confidently to the centre, so that traffic is now moving in both directions in front and behind him.
- He now scans the oncoming traffic in front of him, looking for a second gap.
- He sees a small gap approaching, decides that he can just get through, and sprints forward at right angles to traffic flow, to reach the pavement / side-walk as quickly as possible.
- On arrival, he swivels and slows to a casual stroll, continuing toward the bank, trying to look cool and unflustered — despite the shot of adrenalin, increased heart rate, and the flow of dopamine and serotonin that accompany his risky venture.
- These various “steps” are the “objectives” / “sub-goals”, leading to his “goal”, that form part of his “mission” for which he could have designed a “strategy” consisting of checking for clearance to proceed to which a module attached to a “PMF” consisting of looking at both side of the road before engaging would have been perfectly fine but will at least be part of his new emergent capabilities.

To see what is going on here, first view the young man as a prime example of an **IDA - Information-Decision-Action** — System.

This is a ubiquitous class of systems that collect information, make decisions based upon that information and act, all in real time, or near real time. Many socio-technical systems are IDA Systems, if only because there are people at the foci within such systems. So, an airliner is an IDA system because the crew take in information about their situation, make appropriate decisions and act upon them, taking the whole airliner along with them. Similarly, an army is an IDA system, most particularly where the various forces under command are deployed by a command and control (C2) system, which gathers intelligence and other situational information, makes decisions, formulates a plan of action, and then controls the execution of the plan by deploying forces in co-ordinated actions. Emergency services, enterprises, platoons, air traffic management, and many, many others are IDA systems.

Going back to the young man, it is important to understand that he does not consciously control many of his actions in the way that we might think. To appreciate the issue, conduct a "mind experiment". Imagine that you are seated, and are going to stand up and walk, but that you have to conduct these everyday actions / procedures by conscious control and coordination of each and every muscle in the parts of the body — spine, abdomen, legs, arms, toes, Try it — you will get nowhere — you will not be able even to stand up and maintain balance, and even if you did manage so to do, it would take ages...

Such seemingly simple actions as standing up require a great deal of coordinated activity, sensing and balancing, which we learned as toddlers. The learning became set in our minds as established routines, which can be triggered by "firing" the appropriate "neuron template" in the brain. We set up these templates when we were very young, by trial and error, until we could call up the appropriate routine at will, seemingly without conscious thought. In this way, we can respond to situations very quickly, or smoothly and deliberately, according to situation, by calling up the appropriate neuron template. We can call up templates in sequence, and can transition between them, so we can stand and transition to walking virtually in one movement. We may even be able to "modify" routines in real time, e.g., to stand and walk around an object in one seemingly smooth movement.

Similarly, a concert pianist could not play, say, the Minute Waltz if he/she had to perform by reading and playing each note off the sheet music — it would take too long, and be prone to error. Instead, the pianist learns complete musical phrases which he/she can subsequently "trigger" in the correct sequence to play the piece at speed. Note, however, that the expert pianist can "influence" each musical phrase during a real-time performance, to "interpret" his/her performance.

- Now, going back to the figure above, we can see at the top of the "strand" of PMFs that at least one is concerned with sensing situation.
  - This sensed information allows the IDA system (young man, army, airliner, air traffic management, etc.) to assess the current situation, which seems to be often done either by mental simulation, i.e., observing what is going on and anticipating what is going to happen next...
- Next, the IDA system may choose what action(s) it needs to take to further its intent/and to evade or overcome threats.
  - This is, essentially, the formulation of a plan of action.

- In executing the plan, the IDA system calls upon sets of (sub)routines, standard operating procedures, or learned activity sequences, which can be strung together easily and swiftly, enabling operation in real time or near real time.
- To pursue a particular mission, it may be necessary to activate a variety of PMFs in series/parallel, such that their interactions may result in emergent properties of the whole.
    - This is orchestration or choreography of actions to create synergies — cooperation, coordination, complementation, etc...
    - To “optimize” the degree of synergy, it may be possible to “adjust” the contribution of various PMFs relative to each other.
    - So, there may be 4 Cs of synergy and emergence:
        - Complementation.
        - Cooperation.
        - Coordination.
        - Contribution.

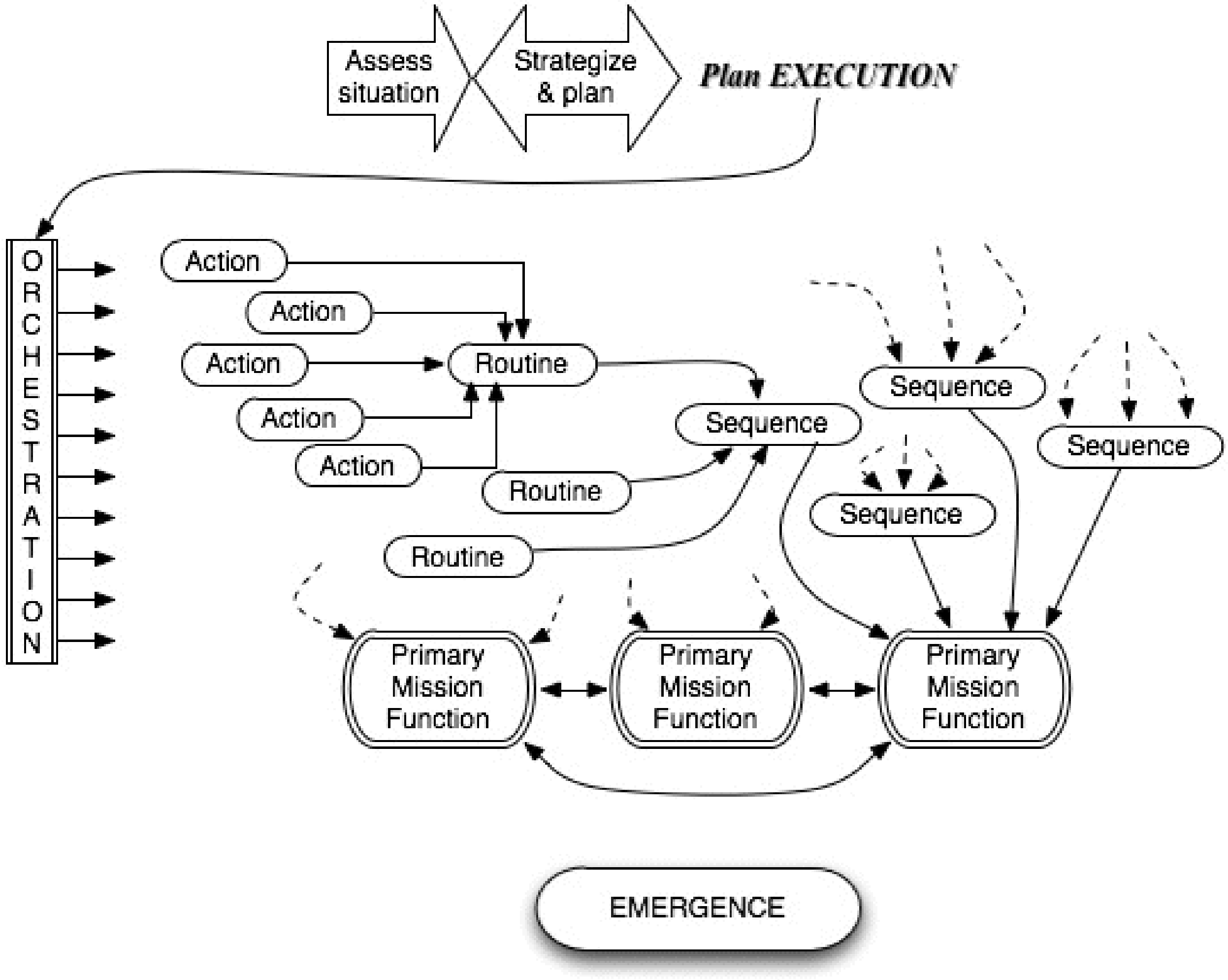
For the young man crossing the road, emergent properties might include agility and teleology. Note that his ability to dodge traffic when crossing the road is unique among animals — no other animal could cross a busy road safely, and in particular, no other animal could behave in such a flexible manner, adapting behaviour to situation and circumstance.

For an army-as-an-IDA system, emergent properties might include flexibility, adaptability, survivability, synergistic concentration of force… etc... The ability to operate in such a flexible, adaptable, responsive manner might make the difference between winning and losing...

The figure shows, further, at top right, the ability to adapt plans in real time as demanded by developing situations. So, the young man, temporarily trapped in the middle of the road, perceives a small gap coming his way, “calculates” (by simulation?) that he can cross though the small gap — just — and chooses to sprint across the second half of the road. So, he modifies the plan and substitutes one or more routines for those previously envisaged when he had anticipated an easier, more leisurely crossing.

The following figure generalizes the process of “designing in” emergence. At the top can be seen elements from the decision-making processes: assess situation, strategize & plan. They connect to the execution of the plan. The execution of the plan involves the system in activating and deploying its primary mission functions (PMFs) — not surprisingly since the plan is inevitably about undertaking a mission... according to what mission, and which strategy characterizes that mission, different PMFs will come into play. Each of the PMFs will be comprise of sequences of routines, each routine being comprised in turn of a set of activities. Execution, then, consists of triggering the appropriate actions at the appropriate times, which constitute activating routines. Routines activated in series / parallel constitute PMFs. Several PMFs operating in a cooperative and coordinated manner my result in emergent properties, capabilities and behaviours.

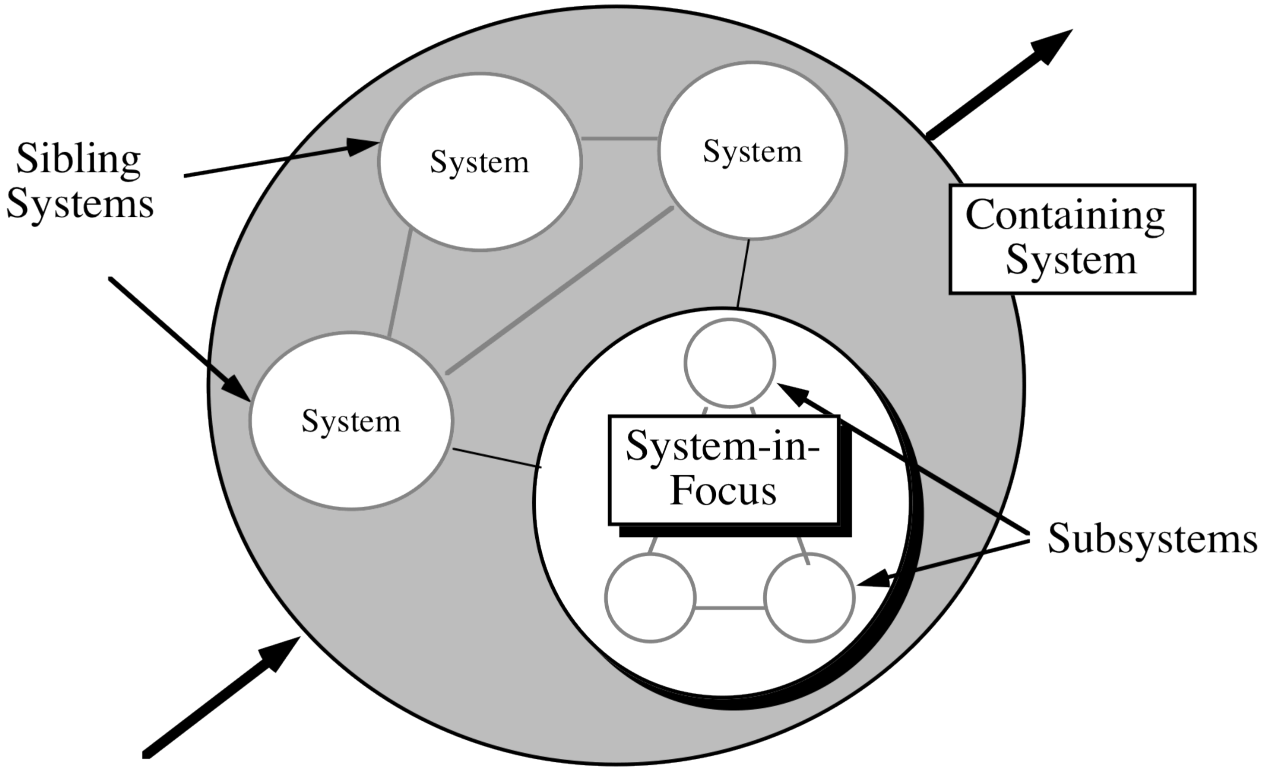
In the figure, the coordination of all of the various activities is referred to as 'orchestration.' The net result of good orchestration is that the various parts of the system cooperate, coordinate, complement and contribute synergistically — and that results both in properly acting and interacting PMFs and in emergent properties, capabilities and behaviours.



Conclusion

Systems ideas, systems science, systems thinking, systems theory and systems engineering are centred around the notion of emergence — it is this feature that characterizes and distinguishes “systems” from other disciplines and pursuits of understanding. For instance, the essence of systems engineering may be seen as the bringing together of the right parts to interact in the right way and for those interactions to be so orchestrated as to produce requisite emergent properties, capabilities and behaviours… It is philosophically possible to “create” emergent properties, capabilities and behaviours to order — indeed, that is, or should be, the driving purpose of systems design and systems engineering.

Systems approach



The systems approach was developed around the middle of the 20th Century, and proved an immediate, resounding success. Essentially, the approach considered a system-of-interest (SOI) to be open, dynamic, to exist in an environment, to interact with — and adapt to — other systems in that environment, and to form part of a larger, wider system. The systems could be of any kind, but are generally characterized as functional, i.e, the systems, subsystems, containing systems, etc., all perform functions and exhibit behaviour.

See the figure above, referred to as "the poached egg" diagram, for obvious reasons. It shows three levels of system hierarchy explicitly, and infers two more:

- The System-in-Focus (SiF) (or System-of-Interest (SOI)) is shown at the nominal level, interacting with three sibling systems — there could be many more.
- The SiF is shown as containing three interacting subsystems (i.e., one level down) — there could be many more of these, too, and each could, in its turn, contain many interacting sub-subsystems (i.e., two levels down) — not shown.
- Similarly the SiF is shown, with its siblings, as being part of some containing system (i.e., one level up) which is, in its turn, shown as having interconnections with other containing systems...
- Suggesting an even higher level of hierarchy — not shown.
- Essentially, then, the poached egg shows three levels of systems hierarchy in an infinite hierarchy of systems within systems within systems, and systems in systems in system... not unlike Russian dolls.
- At each level — the various entities have the properties of an open system (q.v.)(q.v.).
- Observers may position themselves anywhere on that vertical hierarchy according to purpose or interest…

The systems approach, then, considers a System-of-Interest in context, as an open, functioning system, part of some greater/wider/containing system, interacting with and adapting to other systems (siblings?) in the environment. An open system is one that exchanges energy, substance and information with its environment... You and I are open systems, so is a factory, so is an airliner, an automobile, etc... So, when designing a system, or when simulating the functioning or behaviour of a system, the system-in-design is set into surrounding functional systems with which it interacts, and to which it may adapt, while at the same time, the system-in-design is actively operating/functioning, passing throughput from inflow to outflow... and, according to problem, the systems in question could be processes as systems, human activity systems, social systems, economic systems, ecological systems, political systems, theological systems…

Just so long as they are open, interacting, functional systems.

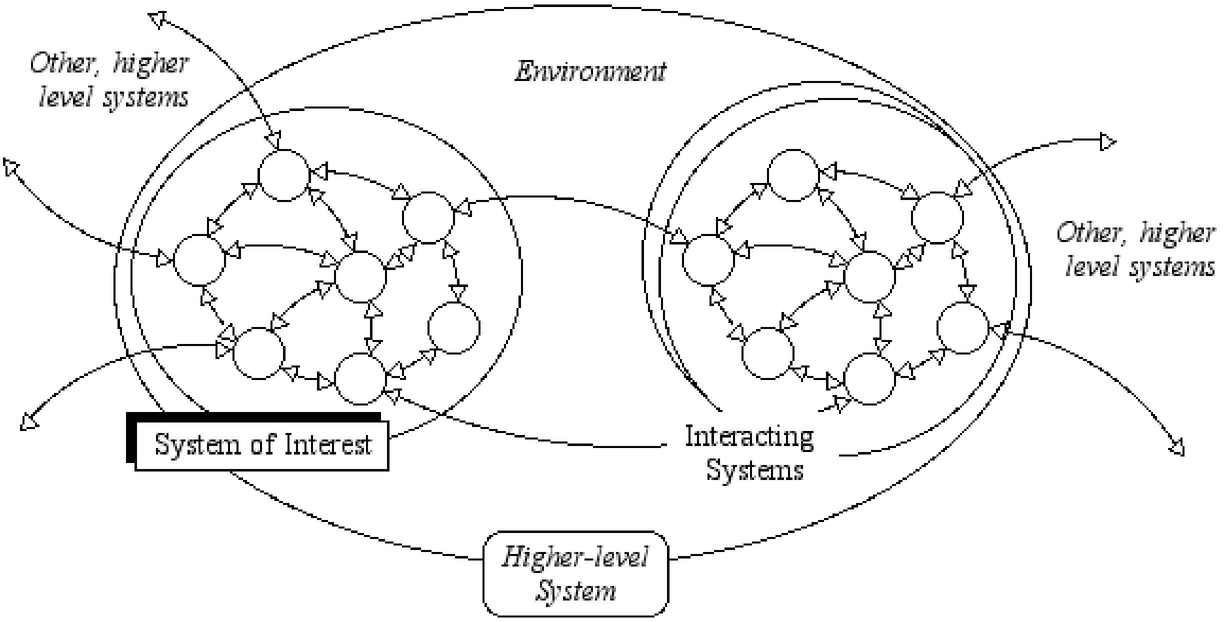
For another view of the systems approach, see the figure below, where the SOI could be any of the small circles, or — as labelled — the larger contained circle on the left, with its “contained” subsystems...

Using the systems approach, it became the practice to understand the behaviour of the part only in the context of the whole, interacting with, and adapting to, its environment. While the hard sciences, notably physics, viewed the systems approach with suspicion, it became “de rigueur” in almost every other sphere of scientific endeavour, including the social sciences, and the life sciences — it had its roots, of course, in biology where there is no rational alternative.

Management and organization sciences, in particular, adopted the systems approach.

The systems approach became core to understanding system behaviour and systems design in systems engineering. Using the approach, systems were seen as dynamic and in operation, acting upon, and being acted upon by, other systems.

The systems approach resolved a significant difficulty in systems design:



- Consider a set of open, interacting subsystems (represented by small circles) comprising an open system (System of Interest in the figure), such that a designer wishes to synthesize particular emergent properties, capabilities and behaviours from this whole System of Interest (SOI).
- The designer (usually working with dynamic models of systems behaviour) may affect the overall system (the “whole”) by changing any of the subsystems.
    - But as he/she (hereafter “he”) changes any one subsystem (small circle), that change impacts on other subsystem to which the first is connected: they will react to the change, and will be changed, too, such that any one change will result in a dynamic reverberation throughout the set, before settling to some unpredictable dynamic steady state (homeostasis).

        - Stability may be an inappropriate term when considering open systems, which reach a dynamic steady state at high energy levels — as opposed to the more usual low energy stability associated with closed physical systems.

- This pattern of behaviour is typical of such open systems. Moreover, the set of subsystems forming the whole exists in an environment in which there are many other wholes, some interacting directly, others indirectly — see figure again.
    - So, reverberation will result in changes to the whole (SOI) which, in turn, will affect other interacting systems — and they in turn, may react upon the whole, causing it to adapt.
- It is possible to analyze this complex behaviour using mathematical techniques, including perturbation methods, and non-linear simultaneous difference equations. However, by far the simplest approach is to employ dynamic purposeful behaviour simulation…

Systems methods

Besides holism and synthesis, there is one other tenet of systems thinking and systems engineering — the organismic analogy. The organismic analogy observes that open systems of all kinds, although they may not be organisms, yet they behave like organisms, with conception, birth, life-cycle and finally collapse, often catastrophic collapse, followed by decay and death.

Examples of the organismic analogy include civilizations, enterprises and businesses, and the former soviet union, with its spectacular collapse in 1989/90.

So, for systems thinking, understanding systems behaviour, and system design, it is more realistic to adopt an organic metaphor for complex systems, rather than a mechanistic metaphor such as that generally perceived by engineers for technological and engineering systems.

Adopting the organic metaphor, then, is compatible with the systems approach in systems engineering for creating an optimum solution to a complex problem.

People, including some engineers — who mistakenly think that systems engineering "obviously" has to be about engineering — have difficulty relating to systems in the abstract. However, systems in the abstract are so very powerful that they form the driving power and thrust of systems thinking, systems design, systems engineering and many, many more.

What is a system in the abstract? Consider the problem of detecting intruders trying to get into a secure building. A specific system to detect them might be a burglar alarm. A system in the abstract would simply be — a system to detect intruders, deliberately without further definition:

such a system has purpose and performs functions, but it has few specifics; no form, no structure, no size, no cost, no concept of operations…

However, if we continue to think about this system in the abstract, we might conceive that it could take the form of:

- A guard dog.
- Under floor pressure sensors.
- Creaky floorboards.
- Closed-circuit TVs with movement sensors.
- CO2 sensors to detect exhalation.
- A cobweb.
- A microphone capable of picking up heartbeats.
- A magnetometer.
- Etc...

Similarly, consider the nature of a conveyance: is it a means of transporting a family by road (abstract description, addressing the purpose of the conveyance) or is it a Toyota RAV 4 T180 2.2 litre D4-D SUV (specific description of a particular model)? Clearly the abstract definition leaves plenty of room for manoeuvre as the total system concept and design develop — it may prove, for instance, that sets of in-line roller skates fit the bill best, once it is discovered that the family has to transport itself at speed through a very busy part of town in the rush hour... or maybe motorized scooters would be better, or a helicopter, or an underground railway? Certainly, prematurely deciding that the Toyota RAV 4 was the solution to some problem before fully understanding the problem would be ill advised — although, it has to be said that the Toyota RAV4 T180 is an excellent vehicle... in the right circumstances.

Using abstractions in this way leaves the door open for innovation, adaptation and flexibility.

System abstraction

By working with abstractions in the first instance, then, it is possible to avoid the trap — so often fallen into — of jumping at some “obvious” solution, which later turns out to be either wrong, or at least far from the best... And, surprisingly perhaps, customers with problems are among those most likely to jump to premature conclusions; telling the systems engineers what they need (i.e., in effect designing the solution themselves) rather than explaining their problem. This is currently referred to as "describing the need."

And, if you think about it, that expression does strongly suggest that the customer has already come up with (what he hopes is) the solution to his problem...

It is remarkable how far one can go in addressing problems, developing conceptual solutions, etc..., by postulating systems in the abstract as performing functions, but without being specific as to form, fit, etc... For instance, a problem — any problem — can be seen as dysfunctional behaviour/interaction between systems, where the systems can be of just about any kind... and identifying which systems are dysfunctional is the first step on the path to conceiving a remedial solution to the problem!

A large part of systems engineering is the process of progressively refining the description and definition of abstract functional systems until the abstract aspects are all eventually supplanted by specifics. Eventually, it may be practical to define all aspects of an initially functional-only system, including form, size, mass, structure, architecture, relationships, interactions, internal processes, intelligence, etc..., to the level that the system can be "instantiated" using technology, or people working together, or most likely people and machines working together... cooperating, coordinating, performing functions, reacting, interacting, adapting, behaving, etc...

Systems in the abstract, or functional systems, or just systems, can interact with each other, can adapt to such interactions, and so can exhibit behaviour — response to stimulus. Functional systems are flexible and adaptable — in the beginning, they have no defined structure to inhibit their essential "squidginess"; this can prove immensely powerful, and really enables the systems approach to address problems that would otherwise be quite intractable. Indeed, using functional subsystems to synthesize whole systems, using the systems approach outlined above, permits the effective design and realization of non-linear systems — something that is presently beyond the classically reductionist methods used by engineers in engineering design and engineering management...

Systems synthesis

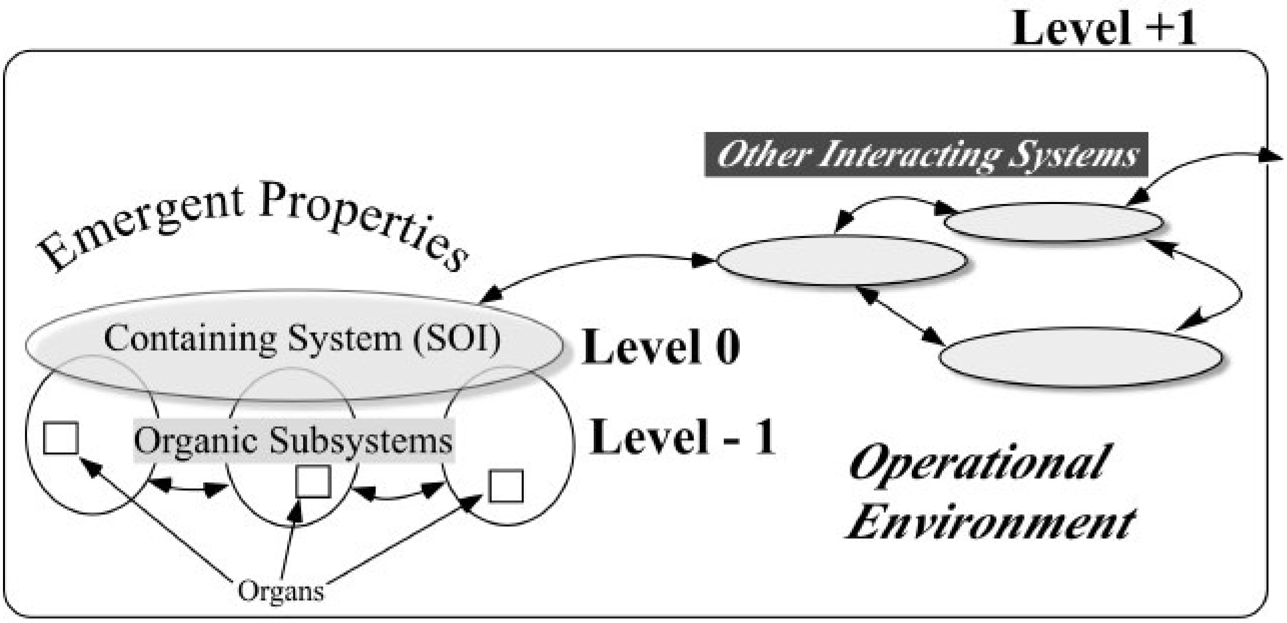
Systems — whole solutions to complex problems — may be synthesized by bringing together appropriate subsystems, and causing them to interact. Being open, these subsystems may adapt to each other as they interact, such that their overall behaviour may prove complex and non-linear. According to classical systems theory, each subsystem, having the characteristics of a system, is capable of exhibiting emergent properties.

Similarly, the whole system, when interacting with other open systems in some operational environment, will also exhibit emergent properties.

> "properties of the whole that are not exclusively attributable to any of their constituent parts, and which may not be meaningful in the terms appropriate at the level of those interacting parts."

Levels of emergence, in this fashion, mark levels of hierarchy in systems organization.

See the figure below:



In the figure, a system of interest is shown at left, comprising a number of "organic" subsystems interacting to form a containing system-of-interest. The containing system, the system-of-interest (SOI), is marked as being at level 0. System hierarchy is a "movable feast", being set to suit the eye of the beholder: in this case, the SOI may be set at level 0 for convenience.

Then, the organic subsystems interacting within it are at level - 1 - down one level of hierarchy. Each of these will contain parts — organs — but we need not concern ourselves with the internals of the subsystems, so long as we can describe the appropriate subsystem in terms of its properties, capabilities and behaviours as it interacts with the other subsystems.

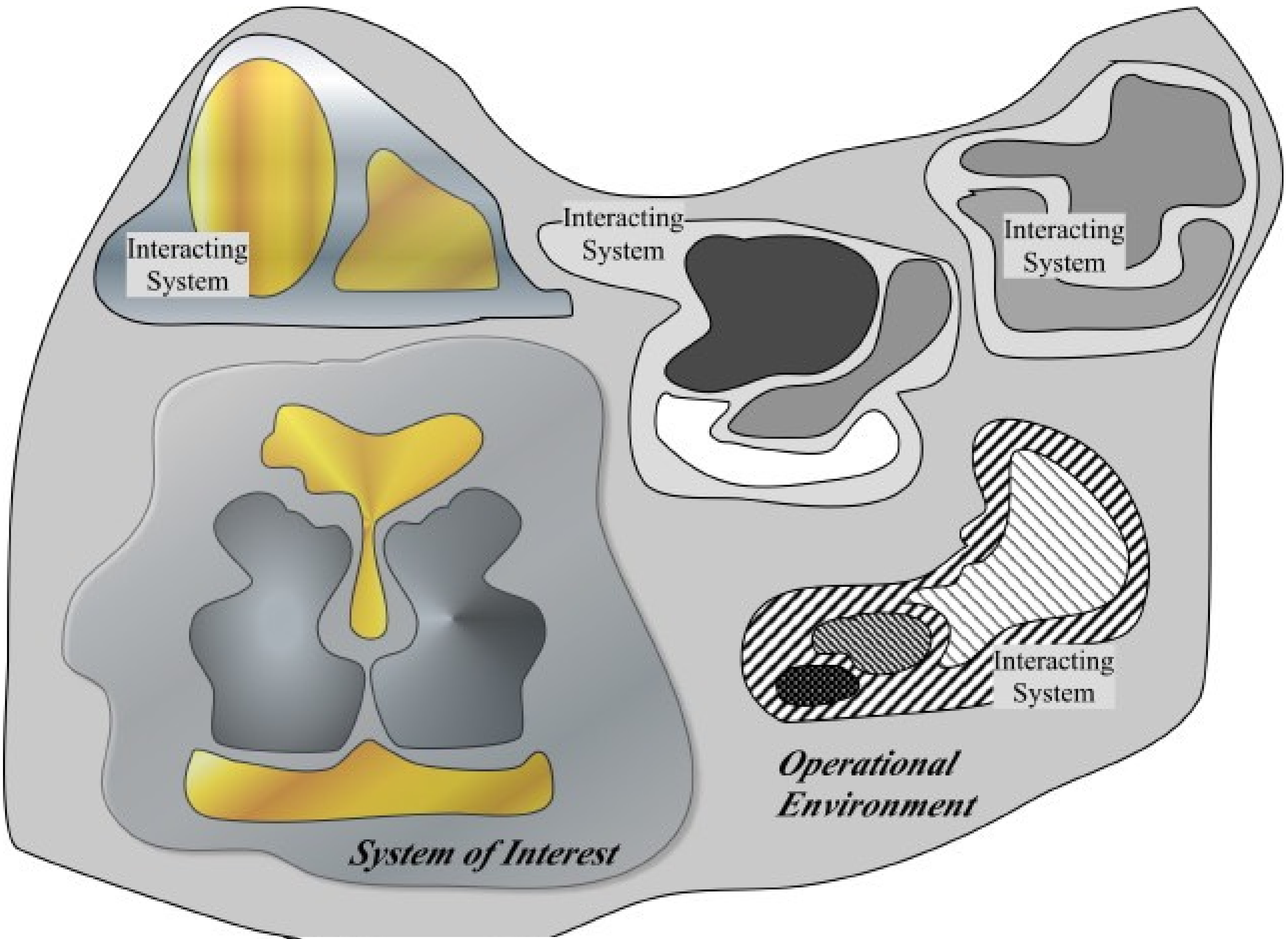
And since each subsystem "sees" the sum of the other subsystems as its environment, it may also exhibit emergent properties to be seen within that environment…

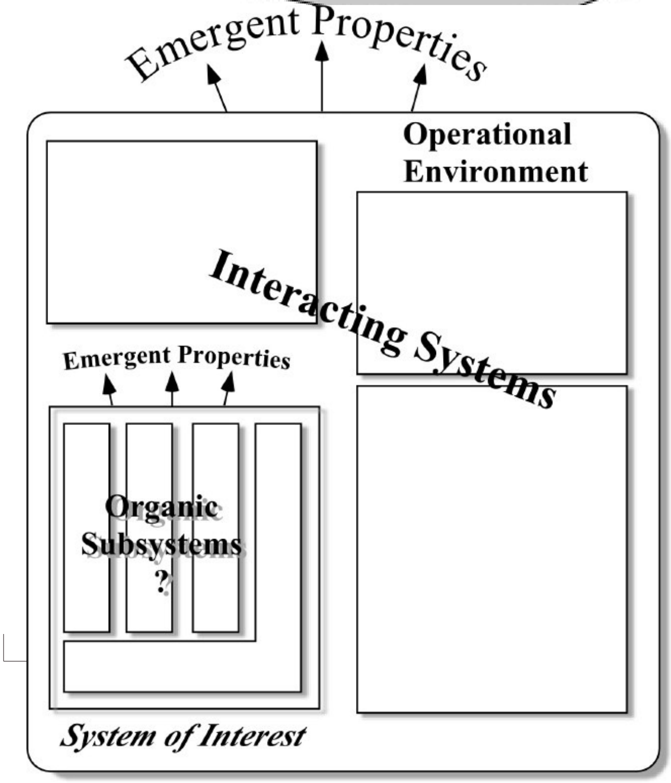
Subsystems are called organic in the figure in recognition of:

- The organic metaphor used by systems engineers, as opposed to the more rigid mechanistic metaphor used by engineers.

- Organicism: “organic” also refers to organicism, a basic tenet of systems engineering, indicating that SE is more concerned with the organization of subsystems at the level of the whole system (SOI), rather than with the internals of subsystems.

“It tend to be the province of engineers, trainers, psychologists, analysts, etc., according to subsystem type.”





The figure above shows a more general view of a systems of interest, interacting with others systems in their common operational environment. Each of the interacting systems reveals its interacting organic subsystems. However, an observer in the operational environment would not see any subsystems: he/she would see only wholes, complete unified, unitary systems. This, then, is perhaps the most basic of emergent properties; that the many interacting parts be perceived, and may be seen to behave, only as a singular entity, when viewed as a whole.

The diagram above may be perceived as a block diagram, referring to technology — although such perceptions are in the eye of the beholder. Again, we can see a system of interest containing organic subsystems, together forming a unified whole, which is interacting with other, seemingly “hard” boxes in their joint environment. As before, there are three levels of hierarchy here, and — although many engineers might be uncomfortable with the idea — emergence can be identified as shown, as the organic subsystems interact, and as the system of interest also interacts…

The synthesis of whole systems, perhaps surprisingly, is directly concerned only with the three levels shown, and is not concerned with the organs or parts within organic subsystems. Instead, it is concerned principally with subsystems, their interactions and their organization, configuration, or architecture — all these terms are consistent with the concept of organicism.

> “Organicism is a philosophical orientation that asserts that reality is best understood as an organic whole. By definition it is close to holism. Organicism is also a doctrine that stresses the organization, rather than the composition, of systems.”

Why the disinterest in organs and parts within subsystems? Each subsystem is described and delineated by its properties, capabilities and behaviours; this renders knowledge of subsystem internals irrelevant in terms of synthesis which, rather than look inwards, is looking upwards and outwards. For an analogy, consider a human body, with its various organic subsystems: skin; bones, joints and skeletal muscles; alimentary canal; urinary system; cardiovascular system; nervous system; sensing organs; respiratory system; energy management system; reproductive system. (There are other way of identifying and describing anatomical subsystems.)

Each of these is a subsystem with parts: the cardiovascular (sub)system has many parts (a heart, arteries, veins, capillaries, muscles, nerves, etc., etc.), but one purpose: to circulate blood throughout the body. The respiratory system also has many parts and has as its purposes the intake of oxygen and the excretion of carbon dioxide. In each case, when thinking about how the whole body functions, it is necessary to consider the various sub-systems, their purposes, their interactions and synergies only; it is unnecessary to consider, say, the heart or the lungs in any detail, since their activities are “incorporated” into, and expressed, in the purpose, performance and behaviour of their containing sub-systems.

Suppose, however, we were to shift our hierarchy perspective down one level, say, to place the cardiovascular system at level 0, then we would become interested in its parts as sub-systems - level-1, and the contribution that the cardiovascular system makes to the whole body, level+1. Then again, we could focus on the heart as level 0, with its atria, ventricles, bicuspid, tricuspid and mitral valves, aorta, superior and inferior vena cava, pulmonary arteries and veins, etc..., etc.., at level-1, and the cardiovascular system at level +1.

So, we are able to move up and down the systems hierarchy, choosing to set our point of focus anywhere that suits us, and we may then refer to that point of focus as level 0. And, to synthesize a whole, we need be interested in only three levels: level-1, level 0 and level +1. This is a valuable perspective, allowing us to greatly reduce any perceived complexity which may be otherwise likely to overwhelm us.

Incidentally, it renders the term “system of systems”, which has become increasingly popular, even amongst those who should, perhaps, know better, rather redundant. From the above perspective, every system is a “system of systems”, just as every system comprises interacting sub-systems. The term “system of systems”, is thus a tautology; not so much wrong, as an error in style revealing that the user of the term is unfamiliar with “systems”.

System models

Fundamentals

The concept "system" is one of organization, structure, relationship, order, method

Systems may be:

- Tangible
- Perceptions
- Transcendentals

One system may exhibit more or less order than another:

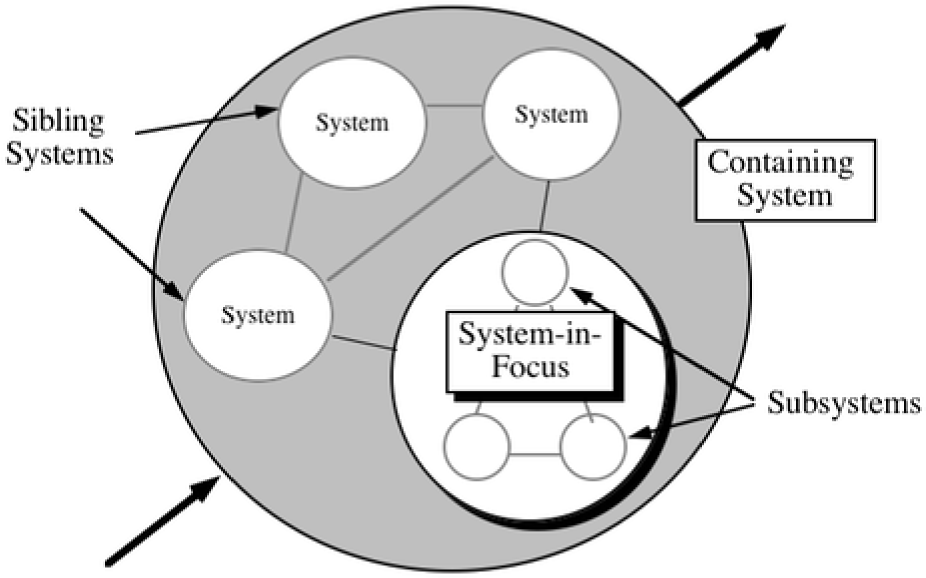
- Degrees of system
- Greater entropy - less system

First system model

This a nesting model, of systems within systems within systems…

- To understand, identify the system of interest (SOI).
    - It contains intra-connected sub-systems, which are systems in their own right, existing within their own environment.

- The SOI is interconnected to other, sibling, systems within their mutual environment, all within a containing system.
- The containing system is similarly connected to its sibling systems (not shown) all existing within their environment. And so on...
- Some siblings may be interconnected through the containing system boundary to systems within other containing systems.



This simple model provides surprising strength and clarity of perception once applied to real situations, to identify real system relationships. for instance:

- In electronics, parts exist within modules, exist within sub-assemblies, exist within assemblies, exist within units, exist within systems, exist within platforms… and so on ad infinitum.
- In management, people exist within sections, exist within departments, exist within divisions, exist within companies, exist within groups, exist within industries…

These ideas of containment and hierarchy couple with the concept of emergence. The containing system above contains several interconnected siblings, including the SOI. Because the SOI and its siblings mutually interact, their combined effect is not the same as though they were virtually separate, like snooker balls in a bag.

Instead, the containing system will exhibit some properties, capabilities and behaviours which emerge from these interactions. As a result, even simple systems, with few siblings, may exhibit quite unexpected behaviour, varying from oscillations to deterministic chaos.

Don't let the simplicity of the model blind you to the potential complexity of the behaviour. That would be to think in static terms. System thinking is dynamics.

System definition and ideas

System:

An open set of complementary, interacting parts with:

- Properties
- Capabilities
- Behaviours

Emerging both from:

- The parts
- Their interactions

The definition presents ideas of:

- Emergence, defining hierarchy, resulting from...
- Interaction
- Containment, nesting, Babushka Russian Dolls
- Completeness, yet...
- ...Openness
- Complementation, hence variety, cohesion, synergy and...
- ...Dynamic stability
- Entropy, internal energy...hence efficiency, effectiveness, net contribution and quality

The first system principle and corollary

First principal of systems:

The properties, capabilities and behaviour of a system derive from its parts, from interactions between those parts, and from interactions with other systems.

Corollary to the first principle:

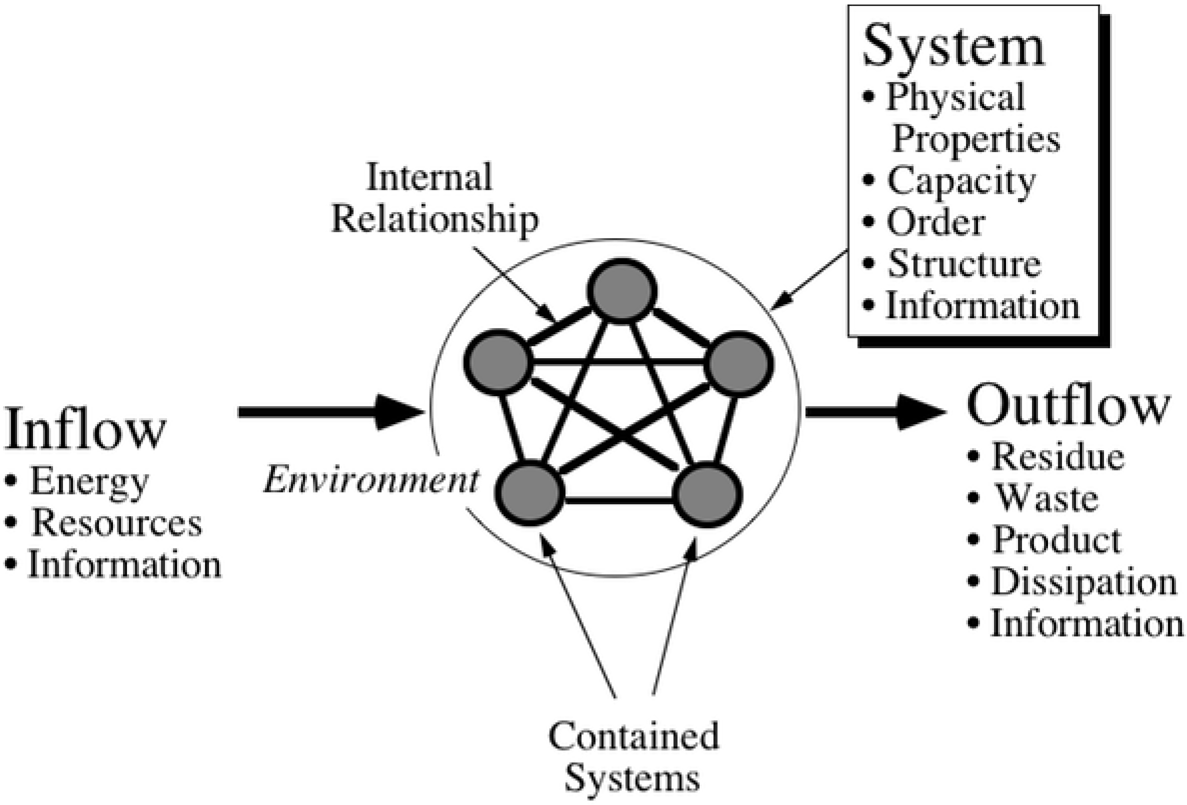
Altering the properties, capabilities or behaviour of any of the parts, or any of their interactions, affects other parts, the whole system, and interacting systems.

Nature of systems models

- Scale independent
- Type independent
- Extensive
- Synthetic, (c.f. Cartesian)
- Address:
    - Emergence
        - Non-linear dynamics
        - Intra-acting synergies
    - Behaviour
        - Stimulus-response
        - Fractal / self-similar
- Deductive/refutable

Second system model

The model shows the same general idea as the first model above, but now the emphasis is on the openness of the system to inflows and outflows. As you can see, inflow might comprise energy, resources and / or information. Outflow might comprise residue, waste and / or product according to your viewpoint about any particular system. and the system itself has properties, shown in the box.



As for the first model, the second model is to be viewed dynamically.

- What happens if the inflow exceeds the outflow?
- Is the containing system stable, does it oscillate over time, is it dynamically stable?
- How is information stored & endash; in the structure?

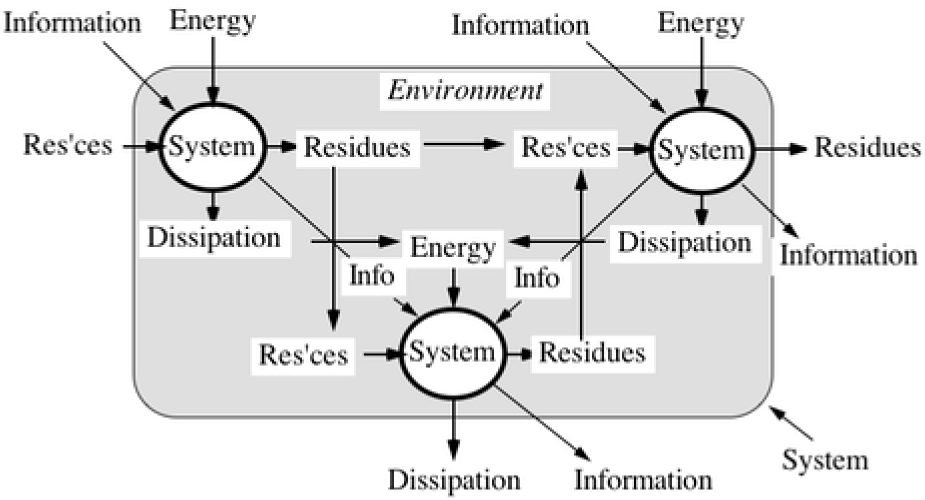
Self-similarity, nesting, recursion and hiding

Another way to look at nesting systems is shown below. Three open systems are shown interconnected. Reading the interconnection legends, you will see that:

- One systems dissipation is another systems energy
- One systems residues is another's resources
- Information is not conserved — it can be passed on without losing it.

The interactions create complementary network. If all three systems are now "hidden" within the system container, you can see that the inflows and outflows from the container are also energy/dissipation, resources/residues and information.

This is self-similarity up and down the hierarchy of containment.



The combination of systems and interconnections may such that each systems requisite inflows are provided by other systems outflows, and vice versa. This situation creates a complementary set of systems. These are common in nature and appear as ecologies.

Economies can operate similarly, both at micro and macro levels.

Generic reference model

Systems methods are very powerful, and can address the solving of complex problems in a way unparalleled by reductionist methods. However, systems methods — which are at the heart of systems thinking, systems, design, systems engineering and the systems methodology — are often misunderstood, since they often rely on representations of systems in the abstract: which can create some confusion amongst hard-nosed, pragmatic engineers, for example! The idea is explained in the Systems Methods, Systems Metaphors, System Abstractions which it may prove advantageous to read before "diving into" the GRM...

The GRM presents an "internal" view of any system. As the map below shows, it is possible to think of any system under three headings:

1. **Being**, the state of existence.
2. **Doing**, the state of activity.
3. **Thinking**, the state of sentience.

Many system simply exist, without directed activity or sentience. e.g. the solar system. Some systems are able to do things, exhibit purpose and pursue goals, e.g. animals, assembly plants.

Yet again, some systems can think, and can adapt their behaviour according to circumstance, e.g. higher animals, companies.

The GRM is developed using several formal approaches, to provide some rigour. As with all good system models, it is type independent and scale independent. It is expanded out in successive levels of decomposition, starting at the top level, the GRM Map.

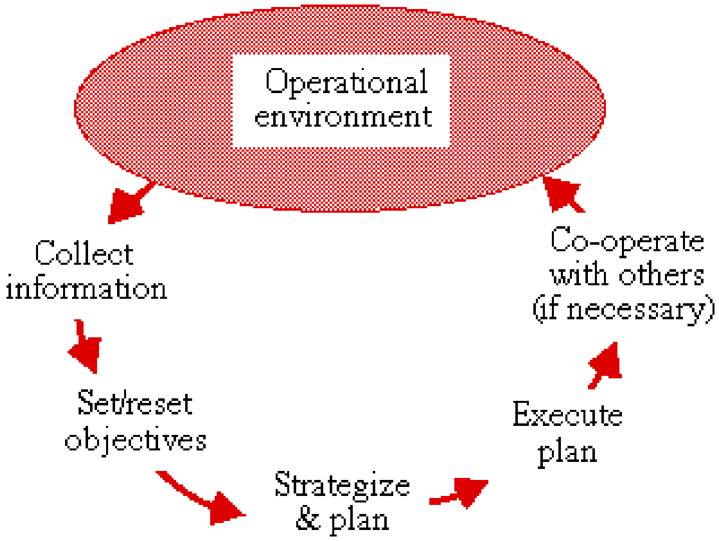
Generic reference: (Function) model

This model describes the "doing" features of any system that has such features. It comprises three parts:

- **Mission** management.
- **Resource** management.
- **Viability** management.

Together, these three form the "management set," so called, because they describe the management of their respective features.

Mission management



All that any system can do in terms of pursuing a mission is to collect information, set or reset objectives using that information (in part) strategize and plan the pursuit of mission, execute the plan and, if necessary, cooperate with others in the environment.

Closure of the circle corresponds with closure, i.e. completeness of the set of the set of continual actions.

Resource management

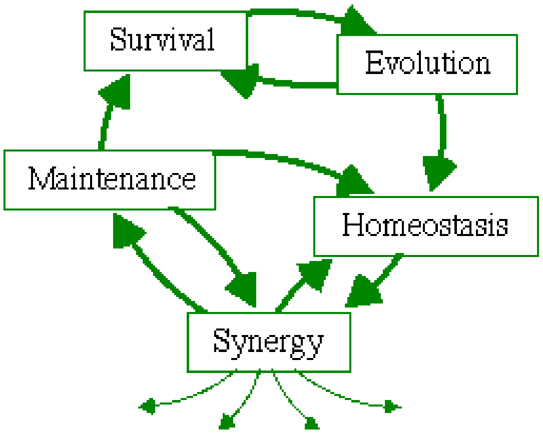
Similarly, all that any system can do in managing resources is: acquire them, store them, distribute them, convert and utilize them, and discard any waste or product.

> "Closure of the circle corresponds with closure, i.e. completeness of the set of the set of continual actions."

Viability management

Viability is altogether more complex:

- For any system to remain viable, it has to maintain its existence within an environment even as that environment may change.
- That environment may engender threats to the system, which may also experience internal defects and deficiencies.



- Through all of this, the internal parts of any system must complement interact with each other so as to provide both a mutually supportive internal environment and to achieve any desired external effects.

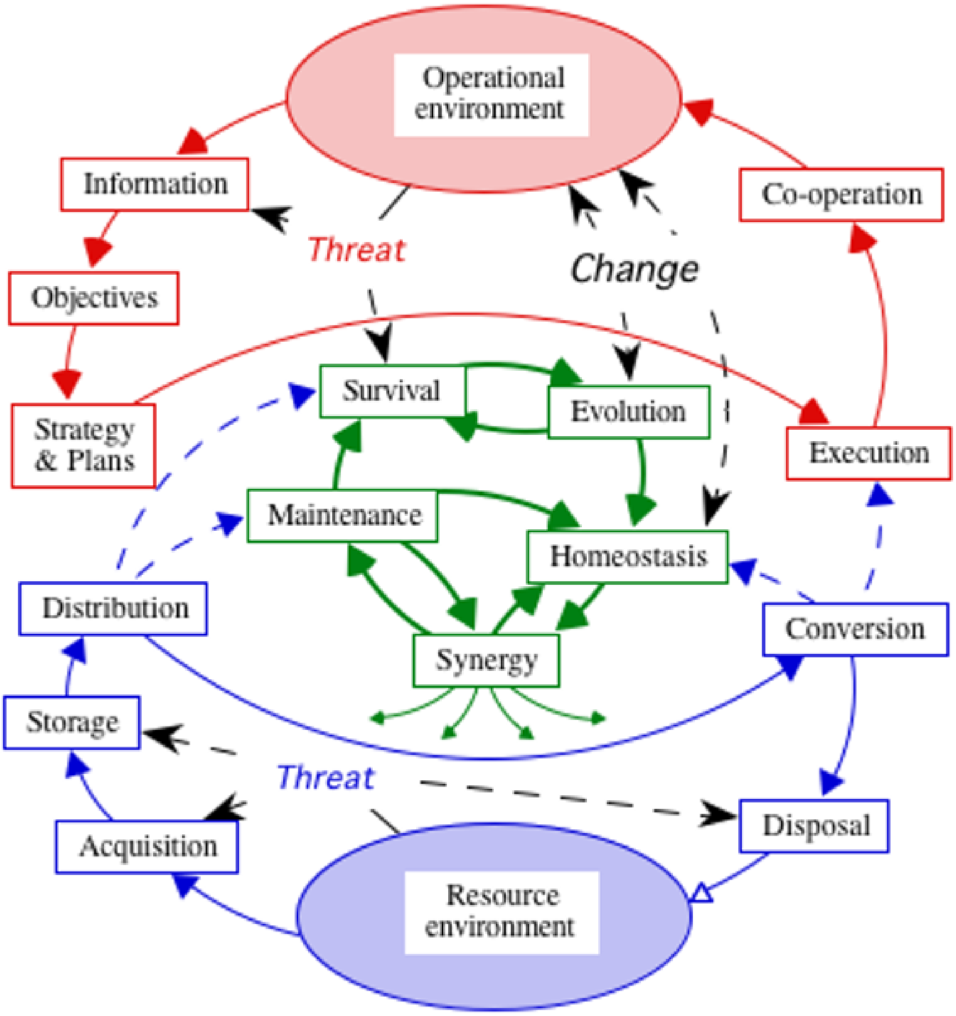
From the above, the following generic features have been carefully extracted to identify the basis of system viability.

Note the mutual interdependence of each feature:

- Homeostasis provides a stable environment within which internal systems may continue to operate efficiently and effectively.
- Evolution, on the other hand, seeks to adapt to change, and so acts over much longer time spans than homeostasis.
- Survival, usually comprised of avoidance of detection, self-defence and damage tolerance, is clearly essential in the short term, but also to enable progressive evolution.
- Maintenance, usually comprised of detection, location, replacement and disposal of defective parts, is also clearly essential for continued viability.
- All of the above provide a basis for synergistic interactions between the parts, but it is also true that synergy between the parts enables maintenance, homeostasis and hence all the others too.

Mission elements together

The three figures above may be combined as shown, to show their mutual interdependence:

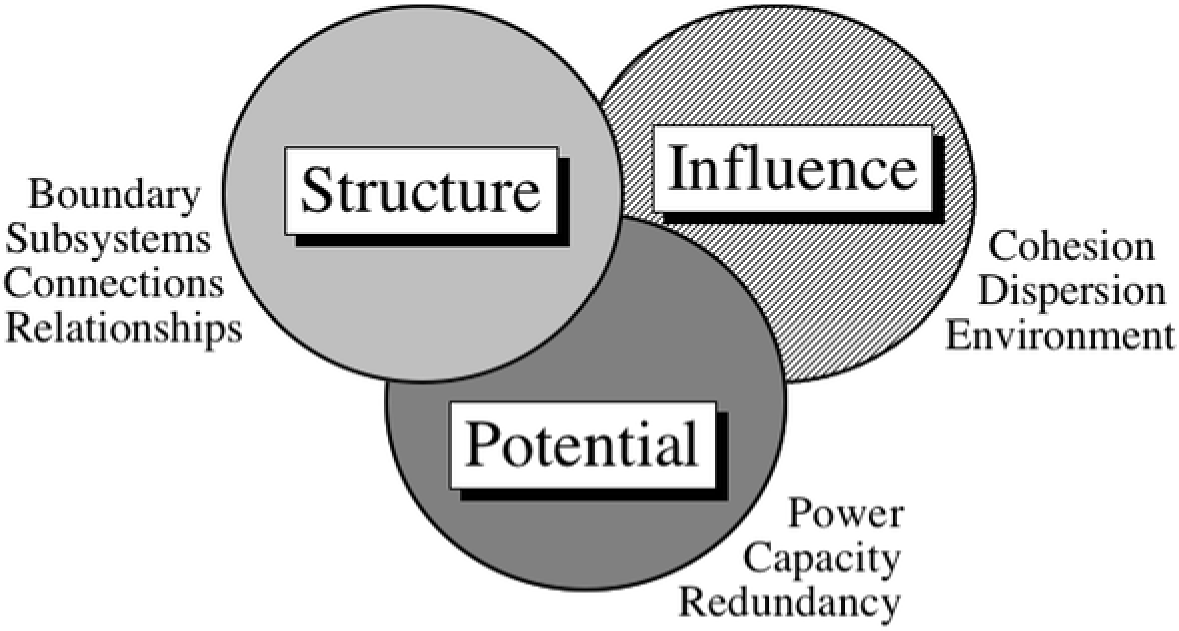


Generic reference: (Form) model

Generic reference (form) model

Form is shown as comprised of three parts:

- Structure
- Influence
- Potential



- Structure and potential are straightforward as shown.
- Influence bases its subdivisions on the concept of system stability, static or dynamic.
    - If a system is stable, the argument goes, then those influences which seek to disperse its parts and those that seek to make them stick together must be in balance.
    - The effect of these influences must vary according to the environment that mediates them — hence the model.

In applying the model to a real-world system, one would have to identify these various influences, of course. Not always easy, but knowing that they must exist is a good start point.

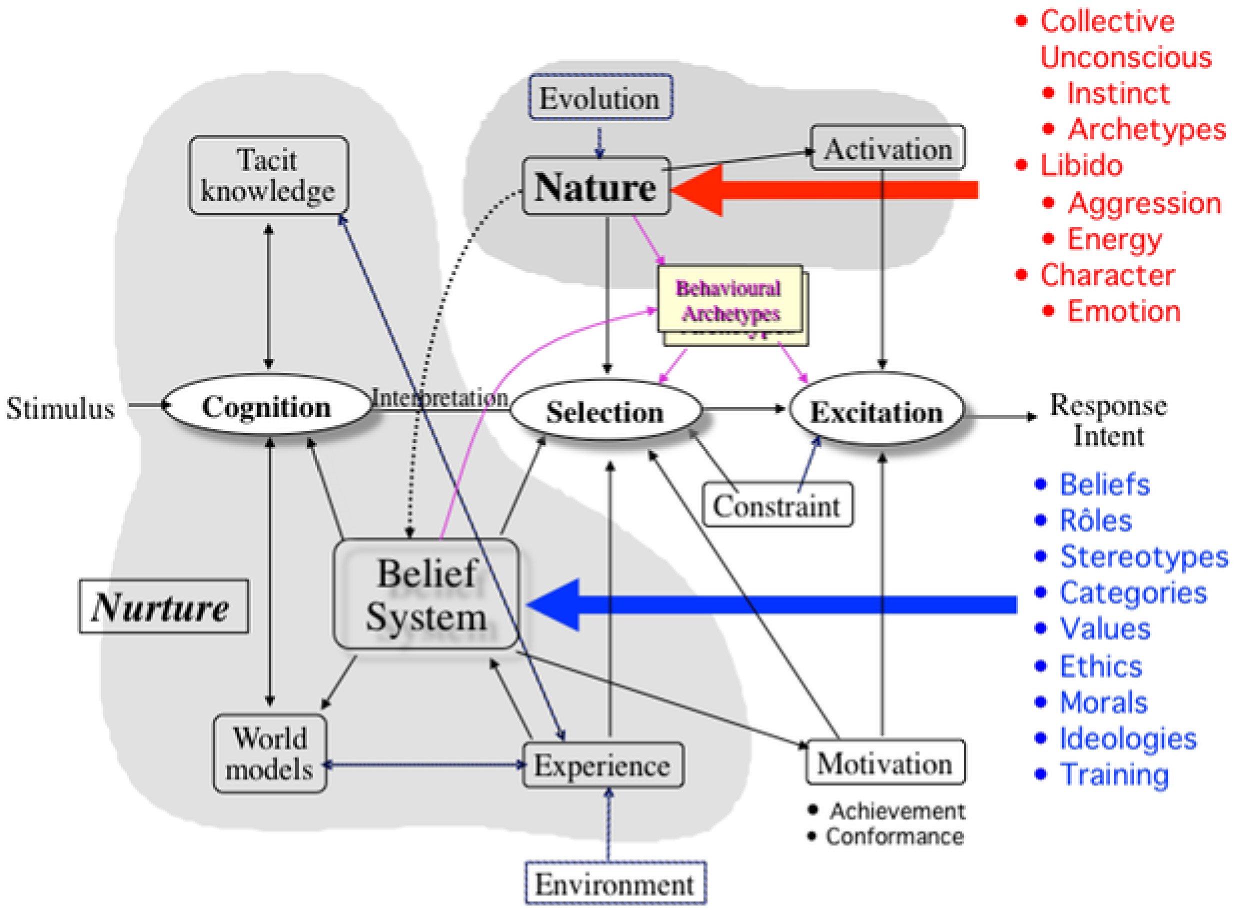
Generic reference: (Behaviour) model

Behaviour model proposes how behaviour might be selected generically:

- Does not identify which behaviour results from a given stimulus.

Of three first-level models, behaviour is the most complex and subtle:

- Based on a variety of psychological models.
- Proposes way in which both instinctive and sentient entities respond to stimulus.
- Appropriate for individuals and groups.
- Recognizes essential nature-nurture conflict.
- Establishes belief as central to behaviour.

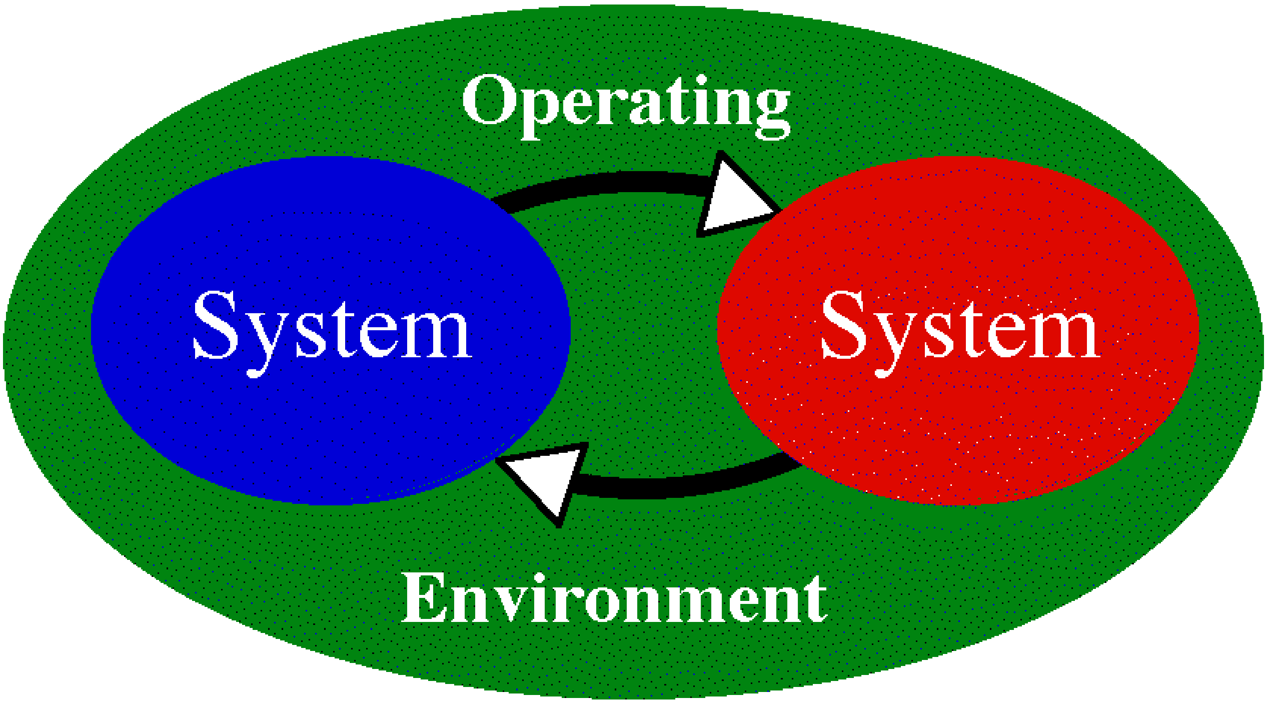


GRM as an integrated whole:

- Possible to view Being, Doing and Thinking elements of GRM as independent
- Useful as a check-list to see if a system description has missing elements, but...
- ...falls well short of full potential
- Different parts of model identify different facets of same system,
    - e.g. Thinking affects the manner of Doing;
    - Doing depends on Being;
    - Being enables Thinking (cogito ergo sum!)

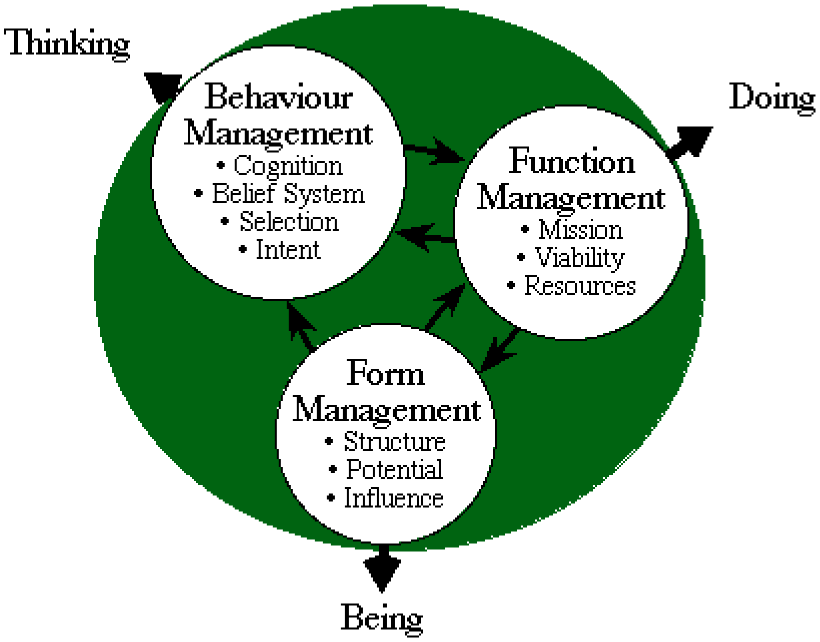
The GRM in action

Instead, the GRM can be used in a powerful methodology for understanding emergence and for measuring effectiveness. Consider the following sequence of figures:

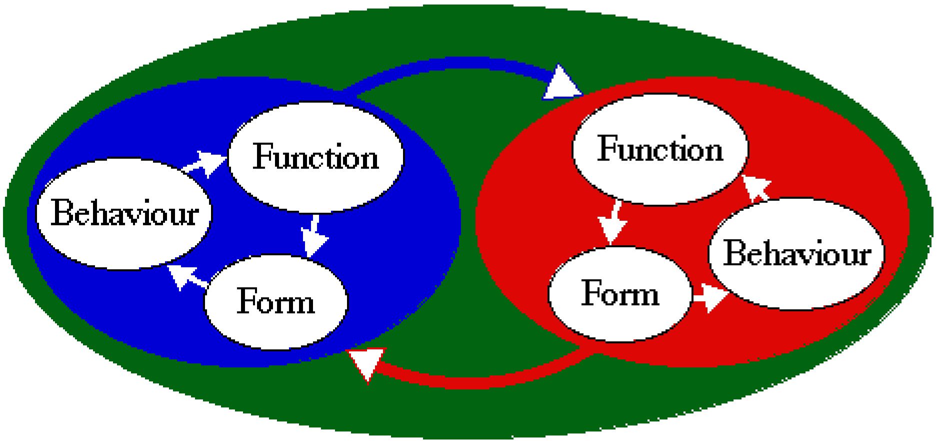


The first figure shows two systems, Blue and Red, interacting in an operating environment. Only in such a dynamic, interactive situation is it possible to sensibly observe, say, Blue's emergent properties, capabilities and behaviours (PCBs). As Blue acts on Red through the environment, Red is affected and changes. This change is a measure of Blue effectiveness. But, Red also acts on Blue, so Blue is changed. Thus, once Red and Blue start to interact, each changes and is changed by, the other. This results in a dynamic, in which the emergent PCBs and effectiveness of both Blue and Red unfold over time. Thus, effectiveness is not some fixed, arbitrary figure, and is not really capable of being specified a priori. Instead it is an emergent property of the interaction of a system of interest (e.g. Blue) when it interacts with other systems in some operating environment.

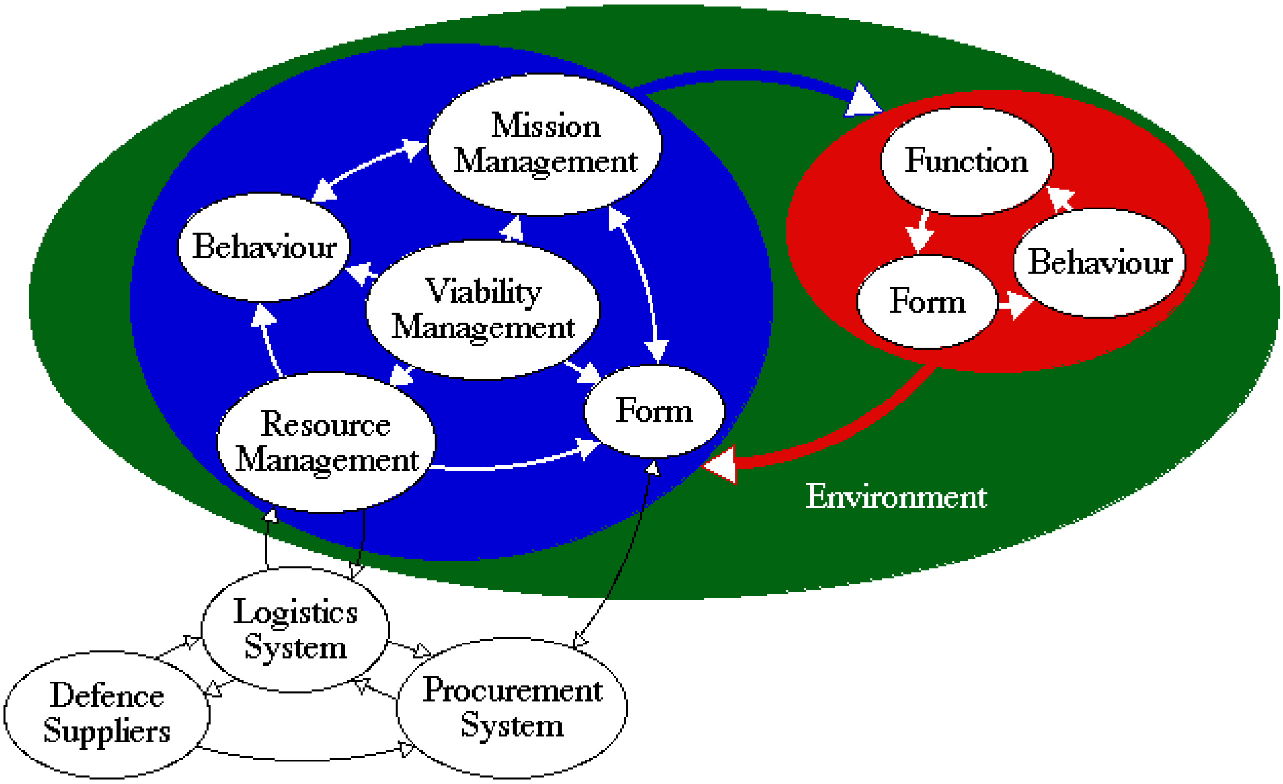
This is not really news. The top speed of a sports car is only some 35 miles per hour when going through the centre of London, say. It may have potential for 135 mph, but that is not what it can achieve when interacting with other vehicles in a transport environment. News or not, people still insist on trying to specify effectiveness as an independent variable, without regard to other systems or the environment. Wrong.



The second repeats the top level model of the GRM



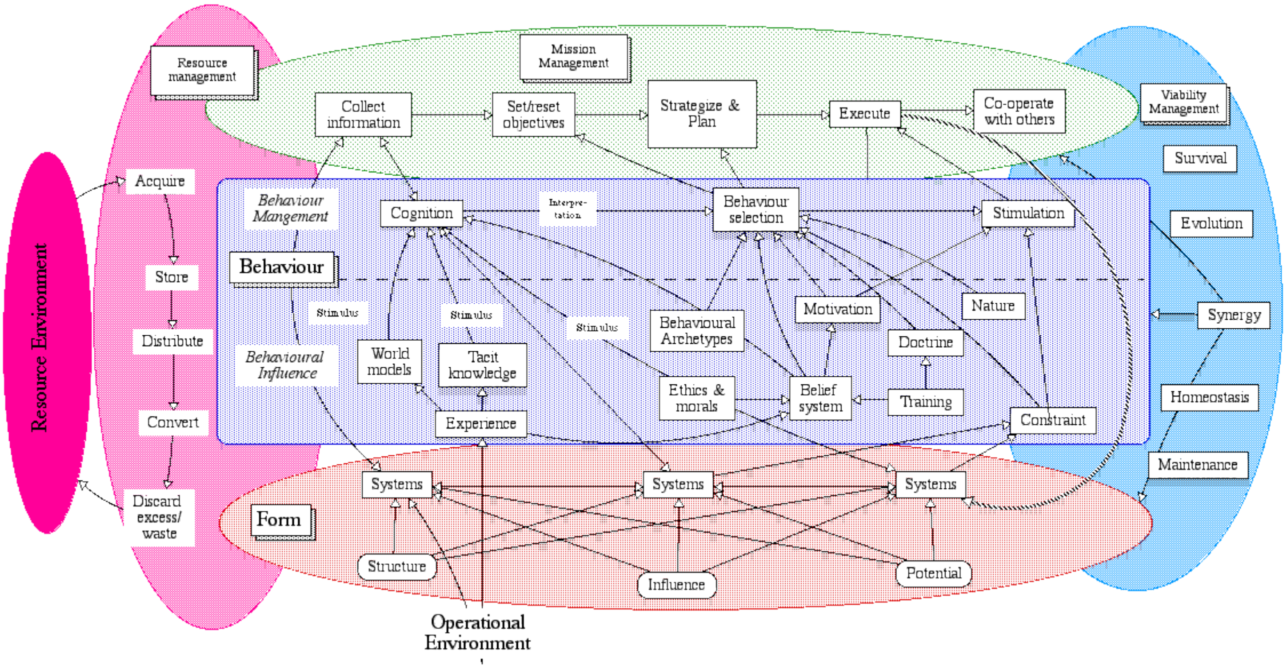
The third figure shows a blue GRM interacting with a red GRM in some green environment



The fourth figure in the series shows how an engaged system such as blue may be related to its logistics, procurement and supplier systems, in this case for a defence system such as a ship, a plane or a tank. Red might have a similar support.

In this way, as shown by the figures, it is possible to employ the GRM as a reference model in active situations. Such situations might include co-operation between two or more systems, competition between systems in some market, or conflict between two opposing groups. The model is still generic.

Finally in this set, the following diagram elaborates the previous Blue GRM to show the level of detail to which you can go — and still remain generic.



The function model has been divided into its three constituents. Resource management and viability management have been set to apply to all three layers, and mission management. This, then, could be used as a C3I model — see "command and control" — where C3I is command, control, communications and intelligence.

This layered model is only half of the model represented in the previous figures, where two interacting systems were seen to be necessary. A useful way forward, then, is to instantiate and replicate the layered model and connect up the two representations so that they may co-operate, compete, or engage each other as appropriate. Instantiations of logistics supply can be added and connected up, as shown in the previous figure. One GRM can be held constant while the other is evolved using genetic or hill climbing algorithms, to achieve maximum effectiveness. The evolved GRM can then be held constant while the first is now evolved. And so on. I call this systolic evolution.

> **"The method and approach are universal, as befits a systems generic reference method."**

There we are — that's a beginning. System models are many and various. Bak and Chen produced a useful model of sand trickling on to a pile, reaching a particular cone size, and thereafter maintaining that size as more sand was poured on, resulting in avalanches.

They called this phenomenon self-organized criticality[1]. They were investigating tectonic plate movement, but the same phenomenon appears to apply to:

- Stock exchange prices.
- Distance between cars on the motorway or free-way.
- Deaths in war.
- Scarce skills in a factory.
- Etc...

So, systems models are many and various — and they can address so many complex things, in ways that conventional approaches simply cannot touch.

---

[1] In physics, self-organized criticality (SOC) is a property of dynamical systems that have a critical point as an attractor. Their macroscopic behaviour thus displays the spatial and/or temporal scale-invariance characteristic of the critical point of a phase transition, but without the need to tune control parameters to a precise value, because the system, effectively, tunes itself as it evolves towards criticality.

System engineering

Philosophy of systems engineering

Abstract

Systems engineering was engendered, partly, to manage rising complexity in man-made systems, which was supposedly threatening to overwhelm engineering managers in the second half of the 20th Century; it was also inspired by a need to “get the best” out of, i.e. to optimize the performance of, complex military systems. The, then, new discipline appears retrospectively to have been founded in biology, rather than the physics of engineering, perhaps since biologists and anatomists had previously found an effective method of managing complexity in the human body. This method could, in principle, be applied in the new discipline of systems engineering to manage complexity, using holism, synthesis and organicism as guiding principles. The paper considers how systems thinking, systems practice and systems engineering were inspired by this systems philosophy then, and now.

Systems engineering emerged as a problem-solving discipline, initially adopting a simple systems engineering problem-solving paradigm that allowed designers to manage complexity, optimize solutions and avoid becoming embroiled in confusing detail at an early stage of systems design. An alternative form of systems engineering developed in Japan, operating at industry level rather than the West’s project/enterprise level. The Japanese also famously employed *kaizen*, the philosophy of continuous improvement, as opposed to the West’s so-called *big bang* approach, (get it) right first time!

Following the biological metaphor, systems engineering could be seen to synthesize wholes from subsystems, themselves wholes. Wholes were made from interacting parts where the whole could be greater than the sum of its parts. The subsystems could be made from engineered artifacts, or people, or teams, etc..., so long as they were wholes. Some “internal systems” could also be seen as organizing and managing other systems within any whole. Ways were devised of conceiving and designing systems such that the complexity did not overwhelm the designers.

A review of systems engineering as it had evolved by 1986 showed that it was limited in its ability to address complex issues and problems: a systems methodology from 2007, based on the original system theoretic biological metaphor, showed the difference between the two. Even more marked, however, was the differences between both of these and today’s version of systems engineering, which describes itself as multidisciplinary engineering, no longer vaunts any claim to the management of complexity, and appears quite unlike its progenitor.

Introduction

Systems engineering was founded, inter alia, in two concepts: first, that it was sensible to view some sets, or collections, of interacting “things”, elements, artifacts, people, etc..., that could be consistently described by their behavior, as singular wholes, holons or “systems”; and second, that it was possible to synthesize more complex systems from parts and systems of lesser complexity. Both concepts transcended the characteristics of discrete parts; in other words, the same principles seemed to apply regardless of the nature of the elements involved.

Systems scientists in the second half of the 20th Century, notably Ludwig von Bertalanffy, expounded general systems theory (GST) (Bertalanffy, 1950). Systems theory and systems science were intended, inter alia, to overcome the increasing degree of engineering specialization prevalent at the time, leading inexorably to increasing complication and perceived complexity, which was supposedly overwhelming engineering managers. GST was heavily mathematical in style, and did not catch on; however, the models and methods of GST were simpler to grasp and are still much valued.

Although the term would not be coined until around 1940 in the US, “systems engineering” as a concept and philosophy may be traced back to ancient Egypt and the Pyramids, if not earlier. In the modern era, it was manifest in the progressive optimization of the UK air defence system over the period 1936 to 1940, at which point it played a crucial role in the battle of Britain. It re-materialized in the Cold War of the 1950s as the total weapon system (TWS) concept, a grand design which, in the UK, saw air defense ground radars, airborne early warning aircraft, and squadrons of Hunter and Javelin interceptors integrated into one system with the single aim of defending the UK against a perceived soviet air threat.

The first real flowering of the TWS concept came in the late 50s and early 60s, with the advent of linesman mediator and the iconic lightning interceptor, reputedly capable of Mach 2+, with climb capability of 0 to 90,000ft in three minutes… but with radar and missile capabilities limited by the need to sustain such phenomenal performance. The ambitious scheme, linesman mediator, saw the coupling of civil and military air traffic to afford nationwide surveillance and control.

Linesman, the military part, was to form a focal point from which all of the lighting aircraft were to be remotely controlled, simultaneously to engage the threat from Soviet standoff weapons, many-on-many (Hitchins, 2007.) The situation eerily presaged the Soviet MIRV threat facing the US two decades on, which instigated president Reagan's strategic defense initiative.

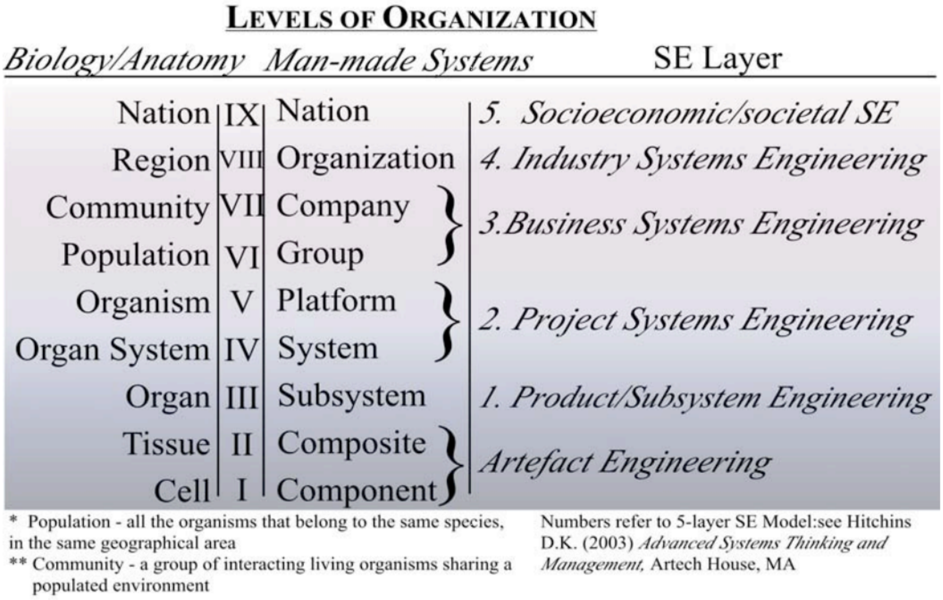
Successive UK air defense systems were more capable and more complex. Systems engineering philosophy and capability evolved, becoming pre-eminent in managing complexity, and with ensuring TWS performance, which was stretching contemporary technological boundaries in defense. In the 1950s, 60s, 70s and 80s, systems engineering became a byword in the West for innovation, creativity and the management of complexity.

The philosophy[2] of systems science and of systems engineering theorizes how these disciplines were intended to manage innovation, creativity and, particularly, complexity. The paper seeks to identify the foundations of that philosophy and how, if at all, it has motivated and sustained systems thinking, systems practice and systems engineering…

Levels of organization

Part of the "systems approach" to managing complexity appears, retrospectively, to have found its origins in biology's "Levels of organization", with which today's schoolchildren may be familiar — see the left hand column of figure 1, which shows the well-known holarchy/hierarchy: cell, tissue, organ, organ system, organism, etc... So, a tissue is more complex than a cell, an organ than a tissue, an organ system than an organ, and so on...

Plus, each level of organization is formed from the emergent properties of the level below, rather than from its intrinsic properties. The center column of figure 1 relates this biological/anatomical holarchy/hierarchy to that of man-made systems.



LEVELS OF ORGANIZATION

Biology/Anatomy		*Man-made Systems*	SE Layer
Nation	IX	Nation	*5. Socioeconomic/societal SE*
Region	VIII	Organization	*4. Industry Systems Engineering*
Community	VII	Company	*3.Business Systems Engineering*
Population	VI	Group	
Organism	V	Platform	*2. Project Systems Engineering*
Organ System	IV	System	
Organ	III	Subsystem	*1. Product/Subsystem Engineering*
Tissue	II	Composite	*Artefact Engineering*
Cell	I	Component	

* Population - all the organisms that belong to the same species, in the same geographical area

** Community - a group of interacting living organisms sharing a populated environment

Numbers refer to 5-layer SE Model:see Hitchins D.K. (2003) *Advanced Systems Thinking and Management,* Artech House, MA

Figure 1: Levels of organization in biology and man-made systems.

---

[2] Study of the theoretical basis of a particular branch of knowledge or experience.

The figure suggests that humans, as organisms ("wholes of interdependent parts"), correspond to platforms, which are typically vehicles, ships, planes, tanks, etc...: this works, in the sense that we humans effectively carry with us, as part of us, our means of locomotion, our sensors, and our intellects, much as does, say, an automobile or a ship.

The right-hand column of figure 1 presents the corresponding layers (rather than levels) from the 5-layer systems engineering model (Hitchins, 2003), with the basic Layer 1, product/subsystem engineering, corresponding to man-made subsystem level: this suggests that the synthesis of subsystems is, relatively, the least complex of SE tasks. The 5-layer systems engineering model, then, concerns itself with managing the synthesis of successive "degrees" of complexity, of which societal/socio-economic systems engineering, as practised, typically, by governments and politicians, is the most complex.

Below layer 1 in figure 1 is artifact[3] engineering, concerned with the making of parts and composites of parts. This is consistent with the acknowledgment that systems engineering does not make anything (sic), at least not in the sense of manufacture i.e., making by hand. Making artifacts is engineering. Managing the making of artifacts is engineering management. It seems eminently reasonable, therefore, that software — a handwritten artifact — is engineering too…

On the other hand, systems engineering may synthesize man-made systems from artifacts previously made by engineers. Systems engineering may also synthesize man-made systems without using artifacts, e.g. in creating an organization (arrangement of people systems), in creating a strategy (a plan of action or policy designed to achieve a major or overall aim), in revising a systems architecture (reconfiguration) with differing emergent properties, etc..., etc...

As with the battle of Britain air defence system in 1940, systems engineering may operate in vivo, as well as in vitro. So:

- A systems engineer may devise, plan and implement new tactics for a squadron of fighters to undertake interceptions, to evade enemy defenses, etc...
    - S/he might be called a "Weapon systems & tactics officer".
- A systems engineer may devise alternative architectures (3:4:3; 4:4:2) and tactics for a soccer team comprised of defenders, mid-fielders and strikers (subsystems).
    - S/he might be called a soccer team coach or manager, and may be unhappy to be called a systems engineer…

In vivo systems engineers may go by alternative titles, happily unaware that they are de facto practicing systems engineers of a kind…

---

[3] Artifact; any object made by human beings, especially with a view to subsequent use.

Systems engineering's concern with emergence and levels of organization so closely parallels that of biology and anatomy that it seems not unlikely that early system scientists employed a biological/anatomical metaphor in formulating complex systems engineering with its powerful approach to managing complexity…

Managing complexity in large-scale complex systems

Using the reductionist hierarchy of figure 1, it is possible to "divide" the complexity of complex organizations, technological devices, socio-economies, etc..., into a succession of hierarchy levels, such that an individual addresses only three levels: the one of immediate interest; the one above, to which an individual may report or refer; and the one below, which "contains" subordinates.

This three-layer concept for managing complexity in both systems management and systems engineering may be elaborated to accommodate large-scale, complex system, figure 2. The figure might be best viewed as looking down upon a cone, at the peak of which is a central systems engineering management team, level N.

Immediately surrounding the center are archetypal systems engineering functions: problem-solving; solution conception; concept of operations (CONOPS); purposing; solution space and threat assessment; functional design; functional/physical architecture; specification of requirements; and so on. Each and every SEM team at levels N-1 and N-2 will perform these same systems engineering functions for their own (organic) subsystems, although at different levels of complexity. Where these SE tasks result in the need for technology engineering and/or acquisition, then the appropriate SEM team will task engineering management/project engineering to design and manufacture to their specification.

In this way, the whole is partitioned into interconnected parts with carefully defined interfaces, such that no individuals or teams find themselves overwhelmed by complexity, each operating within their own 3-layer "scenario": the most complex of challenges may be met and managed in this manner. In practice, such organizations are supported by management and design committees, such that meetings at level N include delegates from level N-1, meetings at level N-1 receive delegates from N-2, and so on. Policy decisions from level N may be passed down through the levels, and problems from the lower levels may be passed up the hierarchy for attention at higher level.

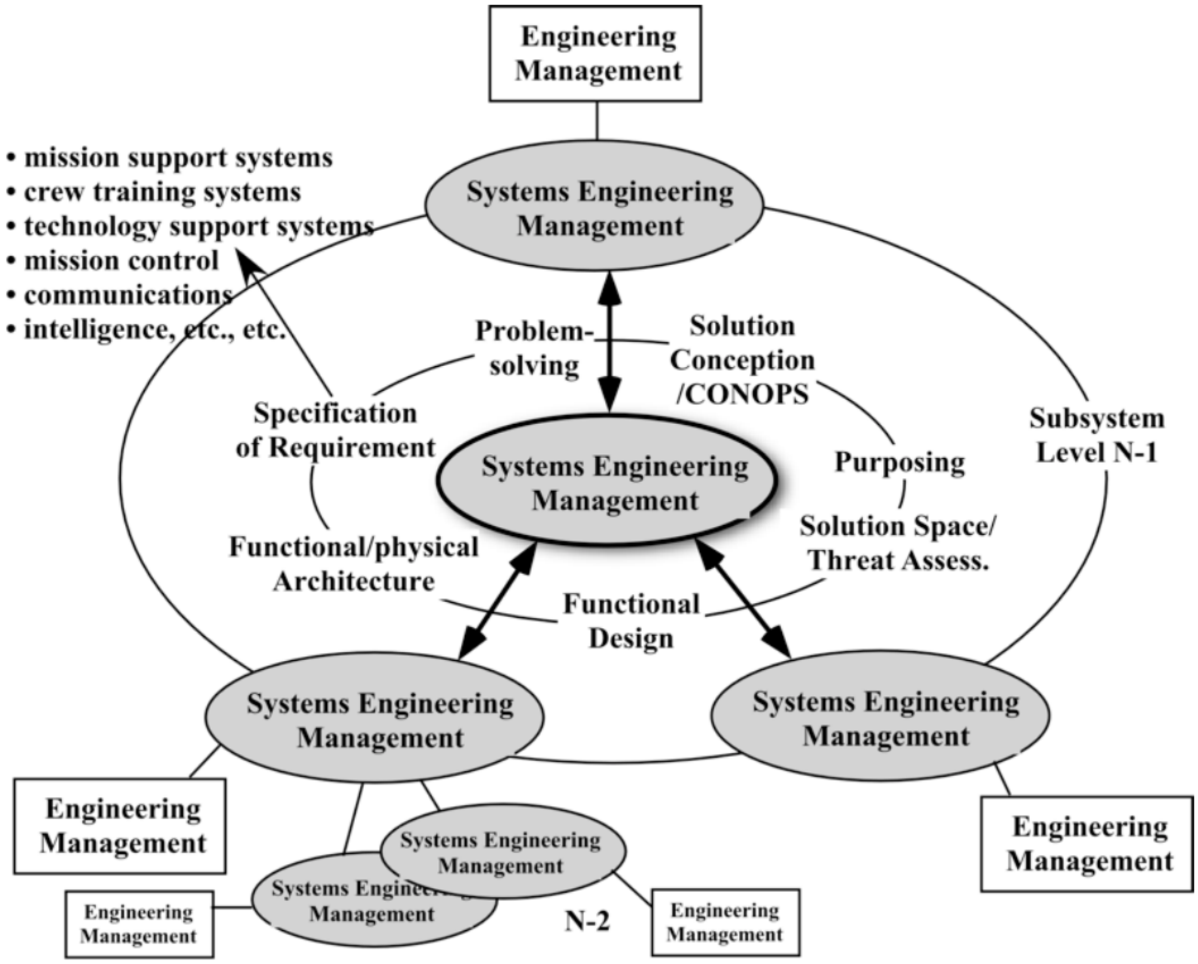

Engineering Management
• mission support systems
• crew training systems
• technology support systems
• mission control
• communications
• intelligence, etc., etc.
Systems Engineering Management
Problem-solving
Solution Conception /CONOPS
Specification of Requirement
Systems Engineering Management
Purposing
Subsystem Level N-1
Functional/physical Architecture
Solution Space/ Threat Assess.
Functional Design
Systems Engineering Management
Systems Engineering Management
Engineering Management
Engineering Management
Systems Engineering Management
Systems Engineering Management
Engineering Management
N-2
Engineering Management

Figure 2: Self-similar systems engineering management schema.

For large scale, complex systems and their programs, then, it appears to be the case that the management of complexity employs the holistic and organismic practices of considering the whole as comprising interacting parts, themselves wholes (holons), and so sensibly evading the detail of what might be "inside" the parts; and also employs corresponding systems management structures and organization.

Systems engineering paradigms

Systems architecting and systems engineering may be concerned, then, with managing complexity, often in large-scale systems and multi-level programs. Managing complexity is neither purpose nor objective, however: systems architecting and systems engineering need purpose in managing complexity. To this end, systems engineering may be described as paradigmatic, and there may be more than one paradigm.

Problem-solving paradigm

Systems engineering in the West has been considered, generally, to follow a problem-solving paradigm. See figure 3, which elaborates the problem-solving paradigm, first to a systems engineering methodology[4], then to a systems engineering strategy and plans to address a problem in context, and finally to systems engineering process, tools and methods to solve/resolve/dissolve the problem in context.

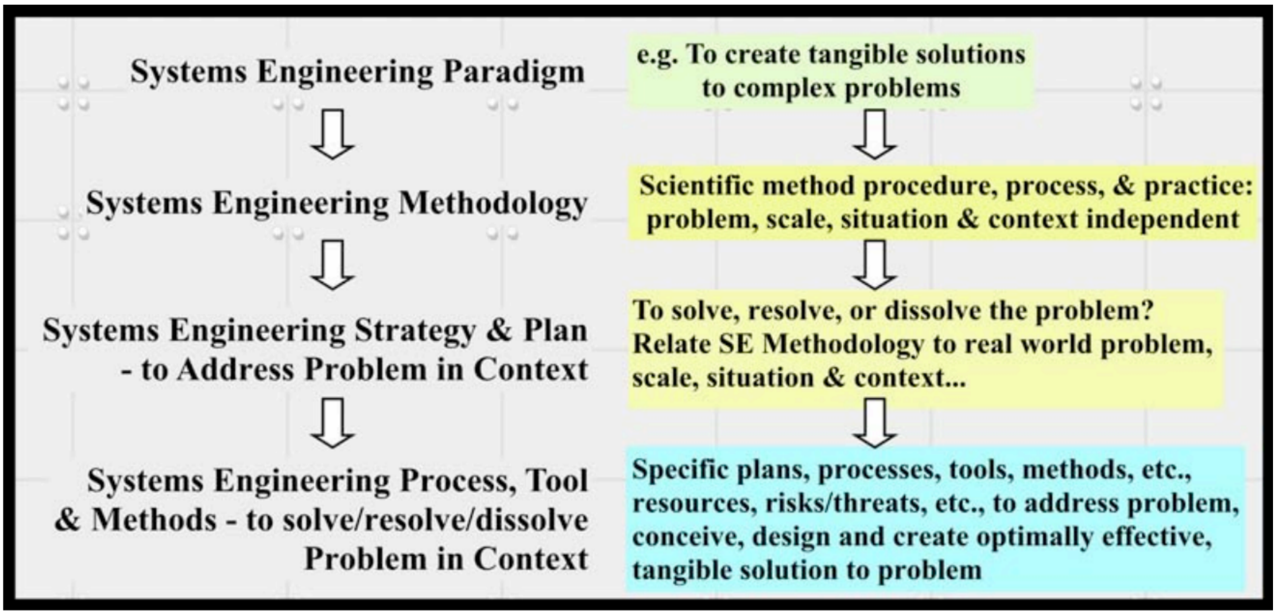

Systems Engineering Paradigm
e.g. To create tangible solutions to complex problems
Systems Engineering Methodology
Scientific method procedure, process, & practice: problem, scale, situation & context independent
Systems Engineering Strategy & Plan - to Address Problem in Context
To solve, resolve, or dissolve the problem? Relate SE Methodology to real world problem, scale, situation & context...
Systems Engineering Process, Tool & Methods - to solve/resolve/dissolve Problem in Context
Specific plans, processes, tools, methods, etc., resources, risks/threats, etc., to address problem, conceive, design and create optimally effective, tangible solution to problem

Figure 3: Elaborating from the systems engineering problem-solving paradigm.

It follows from the figure, that — while conceivably there may be one archetypal systems engineering methodology — systems engineering strategies and plans may vary according to the problem in context, and in particular upon whether to solve the problem (i.e. find a “correct,” or “best,” answer), resolve the problem (i.e. find a solution that satisfices, is “good enough,”) or dissolve the problem (i.e. change the situation such that the problem no longer arises, or becomes insignificant). (Ackoff & Emery, 1972.).

Japanese continuous circular flow paradigm

Toyota in Japan has developed a substantially different way of going about systems engineering on the grand, global scale, one that might be said to follow a “continuous circular flow paradigm.” See Figure 4, showing a clockwise “market pull” concept, where nothing is made unless it is already sold, complemented by an anticlockwise flow of money. (Womack, 1990.) A lead company assembles parts from a “fan-out” of supply companies. The lead company supplies to the market. Unlike mass production, however, the flow of materials, parts, sub-assemblies, etc…, occurs only on demand. The aim is to reduce work-in-progress to a minimum, ideally to zero, and at the same time to have a steady flow of products being sold to the market. The market is encouraged to "demand" by continual innovation, making each new product so attractive that it becomes a "must-have" to the customer.

---

[4] Methodology: a system of methods used in a particular area of study or activity.

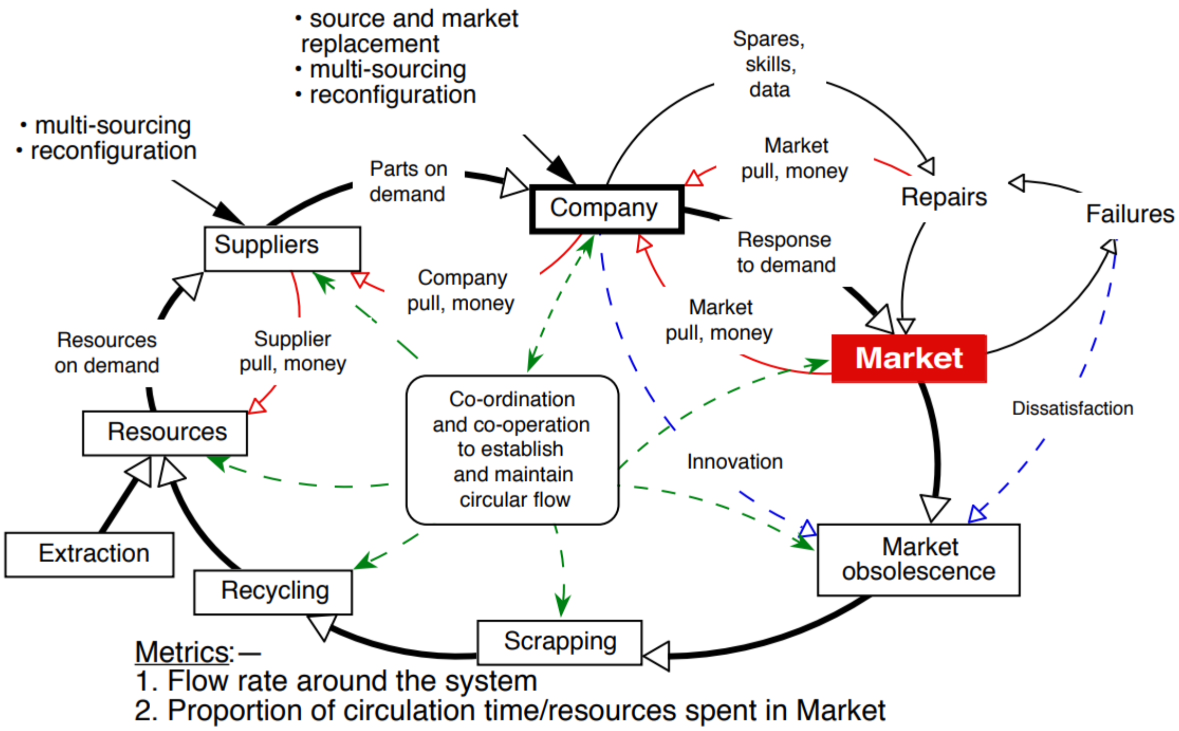


Figure 4: Lean volume supply circular concept (Hitchins, 2003).

Recycling obsolescent vehicles completes the circle, reminiscent of the Ouroboros, the ancient symbol of the snake or dragon eating its own tail, representing the perpetual cyclic renewal of life, the cycle of life, death and return, leading to immortality. Certainly, the circle is seen as strong, with no point of entry or exit, with no beginning or end, and — since the elements within it are being continually adapted and renewed — the lean volume supply circle has no perceivable life-cycle…

Optimization within this paradigm is through *kaizen*, such that elements in the circle are continually being adjusted and adapted to improve overall "circular performance", reminiscent of the earlier progressive optimization of the UK air defence system.

Comparisons: There is, however, a significant difference between the continuous (virtuous?) circle of Japanese industrial systems engineering and the West's problem solving systems engineering: in the West, the cycle is usually seen as a continual arising and solving of problems, with each solution comprising some new or modified system to be delivered to a customer.

In Japan, the industrial circle is the system solution, i.e., the systems architects and systems engineers exist and operate continuously within, and as part of, their solution system, which steadily rotates material — innovative products — around the loop. So, their systems engineering is of the operational variety, in that they are continuously improving, enhancing and rebuilding the system in which they exist, perform and operate — in this respect, they are their own customers.

This practice is consistent with *kaizen*, the Japanese philosophy of continuous improvement, which contrasts markedly with the West's "Big Bang" philosophy of "Right First Time". Comparing the Japanese approach with that of US mass production at the end of the 20th century, a distinct difference could be seen. See table 1 (Hitchins, 2003). As the table suggests, the philosophical differences between US mass production, Henry Ford style, and Toyota's lean volume production, are legion. (Womack et al, 1990).

Mass production	Comparison	Lean volume supply
Profit	Objective	Survival
Free	Competition	Between circles
Free market	Regulation	Indignization
Production push	Assembly	Market pull
Cost plus	Pricing	Market minus
Adversarial	Contract	Synergistic
Specialist	Defense	Homogeneous
Hire and fire	Labour	Jobs for life
Specialisation	Skills	Multi-skilled
Lowest bid wins	Suppliers	Vital source — protect
Supplier stocks	Inventory	Nobody stocks

Table 1: Comparing 20th century US mass production with Japanese lean volume supply.

Complexity and systems engineering principles

Systems engineering seeks to solve complex problems by creating one or more system solutions comprised of interacting subsystems: the subsystems and their interactions are designed and configured to cooperate and coordinate their various functions and actions synergistically to create a unified whole, which will perform with optimum effectiveness in its operational environment and context. Systems engineers, in effect, seek to predict a future in which the yet-to-be-created solution system solves the complex, now-and-future problem. To achieve this, systems engineering draws upon a priori knowledge of how systems and subsystems behave in context, coupled with simulation and testing of proposed solution systems in their anticipated context and environment.

In seeking a solution to any complex problematic situation, systems engineering may observe three guiding systems principles, which require justification:

In seeking a solution to any complex problematic situation, systems engineering may observe three guiding systems principles, which require justification:

- **Holism:** The theory that parts of a whole are in intimate interconnection, such that they cannot exist independently of the whole, or cannot be understood without reference to the whole, which is thus regarded as greater than the sum of its parts.
  - Holism requires that the systems architect/systems engineer focus and practice on the whole system; whole problem, whole solution, in context:
    - Providing less than the whole solution fails to solve the whole problem.
    - Addressing only part of the problem permits the unaddressed problem-parts to aggravate the problematic situation, so potentially counteracting any part solution… (Lewin, 1949).
    - Context is vital to anticipate emergence, performance and effectiveness.
  - Holism also invokes the subtle notion of concinnity, such that the various subsystems balance function, form, behavior and configuration in comprising the whole.
- **Synthesis:** the combination of parts — subsystems — to make a unified whole. It is the antithesis of reductionism, decomposition and analysis:
  - As figure 1 showed, each level of organization comprises the emergent properties of the level below. It follows logically that to create some whole, the system parts must be brought together in interaction, to engender the emergent properties of the interacting system parts. Since this applies at each and every level, synthesis becomes the sine qua non for creation of complex solutions…
- **Organicism:** Organicism emphasizes the organization, rather than the composition, of systems:
  - Organicism emphasizes the way in which the system parts are brought together, i.e. their functional/physical architecture.
  - Organicism may be seen as an aspect of synthesis.

The three guiding principles infuse the proper practice of systems engineering. Holism, for example, pervades systems design optimization, which seeks the best operational solution-in-context. Such optimization of the whole may be effected by:

- Altering/rebalancing the emergent properties of the various interacting subsystems (synthesis).
- Amending the interactions between the subsystems — making new connections, changing connections, altering the degree of interactions (binding and coupling).
- Re-organizing/reconfiguring subsystems to form different functional/physical architectures with different emergent properties (organicism).

Systems engineering and innovation

The systems engineering problem-solving paradigm (SEPSP), figure 5, has been used to solve problems for over sixty years, not only in systems engineering, but also in industry, commerce, management, economics and politics. The idea is disarmingly simple. Having defined a problem space, conceive a number/variety of optional solutions and — independently — identify criteria by which to judge a good solution. These might include feasibility, performance and effectiveness across a range of foreseeable environments and contexts, availability, survivability, affordability, risk, and so on… The solution options are then traded against the various criteria to find the preferred option (best fit), which would be deemed optimum, or “best in context and circumstances.”

By introducing a variety of optional solutions, the door is opened to innovation — for, perhaps, a different way of doing things, or using different technology, or introducing automation, or having a self-healing solution, or going for the cheapest option that might do the job, or choosing the most effective regardless of cost…

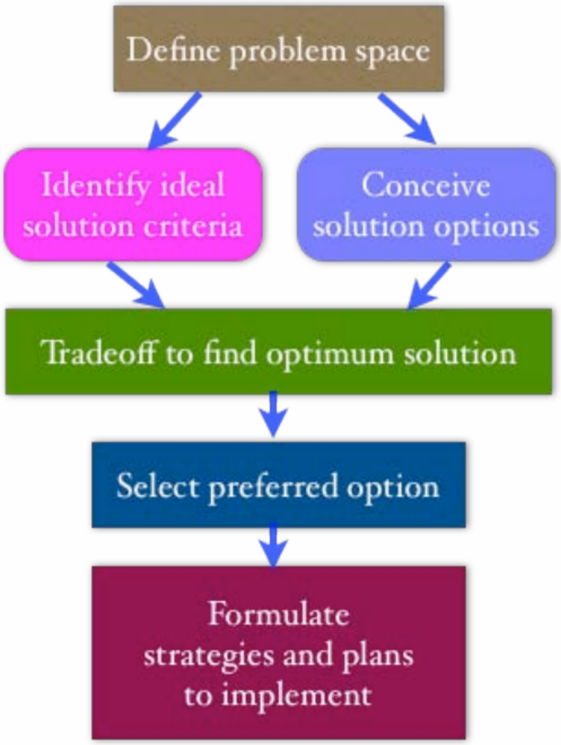

Define problem space
Identify ideal solution criteria
Conceive solution options
Tradeoff to find optimum solution
Select preferred option
Formulate strategies and plans to implement

Figure 5: The systems engineering problem-solving paradigm.

The systems engineering problem-solving paradigm can be used extensively throughout a project. Some organizations have employed the SEPSP as an in-company mantra, employing it on a team-by-team basis, sometimes several times a day, whenever a decision had to be made. The results were impressive, perhaps because it necessarily included many of the systems engineers in decision-making, which not only improved decision-making, but also created a sense of inclusion in these so-called systems thinking organizations.

The general problem-solving paradigm

While the systems engineering problem-solving paradigm is valuable in decision-making, it is not particularly helpful when it comes to exploring and solving complex problems. Problem investigation and solving is crucial to complex systems engineering. One approach is to employ the general problem-solving paradigm (GPSP) shown diagrammatically as a procedure in figure 6.

The procedure is straightforward: first, nominate the issue (problematic situation) to be addressed; then, following the procedure, identify problem components, group them into problem themes, and model these themes to create an ideal world, i.e., one in which the problems do not appear; then compare this ideal world with the real world and all its problems, and use the differences as an agenda for change, resulting — hopefully — in improvements to the problematic issue. Towards the end of the procedure, as indicated by the decision diamond, verify that the change agenda, if implemented, would eliminate the original set of symptoms, else repeat the procedure since some problems may have been overlooked…

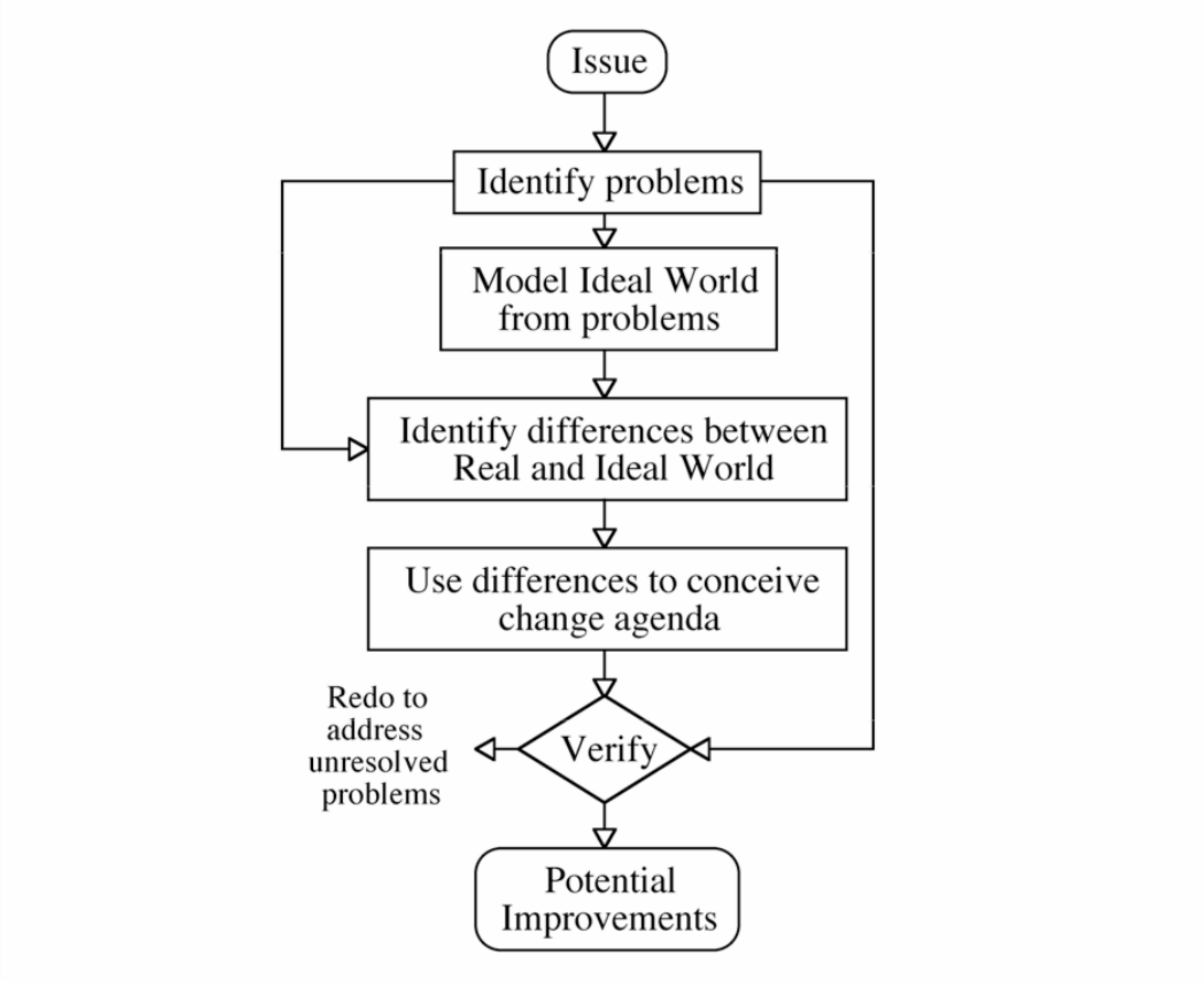

Issue
Identify problems
Model Ideal World from problems
Identify differences between Real and Ideal World
Use differences to conceive change agenda
Redo to address unresolved problems
Verify
Potential Improvements

Figure 6: General problem-solving paradigm (GPSP) (Hitchins, 2007).

Creativity and innovation in systems conception and design

One aspect of problem solving not adequately addressed by the GPSP is that of creativity and innovation within the “change agenda” — which essentially comprises solution-systems conception, CONOPS, and systems design.

Innovation does not result from prescriptive process. It is the product of human ingenuity and creativity: this can be promoted by bringing together a group of people of contrasting backgrounds, skills and experience who may interact in a creative, supportive, non-pejorative environment; systems engineering management creates that environment.

The early stages of systems engineering may be characterized by series of brain-storming sessions, some including customers, stakeholders[5], future user-operators, domain experts, experienced and inexperienced systems engineers, etc. It is the mix of bright, open-minded people and the uninhibited environment that generate fresh, new ideas. So, inevitably, no smart people — no innovation: authoritarian control — no innovation: prescriptive process – no innovation.

Pursuing the CONOPS can create a significant variety of strategies and consequent prime mission functions (PMFs) to effect those strategies[6]. Why PMFs? To distinguish such “externally visible” functions from the “internal” functions that must take place within the system in the management of the PMFs: see figure 7. In any mission, the many PMFs may not be active all at once. Some may not be active at all, but exist as safeguards, or precautions. So there arises the need to “orchestrate” the cooperation between, and the coordination of, the many PMFs. In complex systems, too, the PMFs may provide overlapping and inconsistent data, which then has to be merged according to source error characteristics.

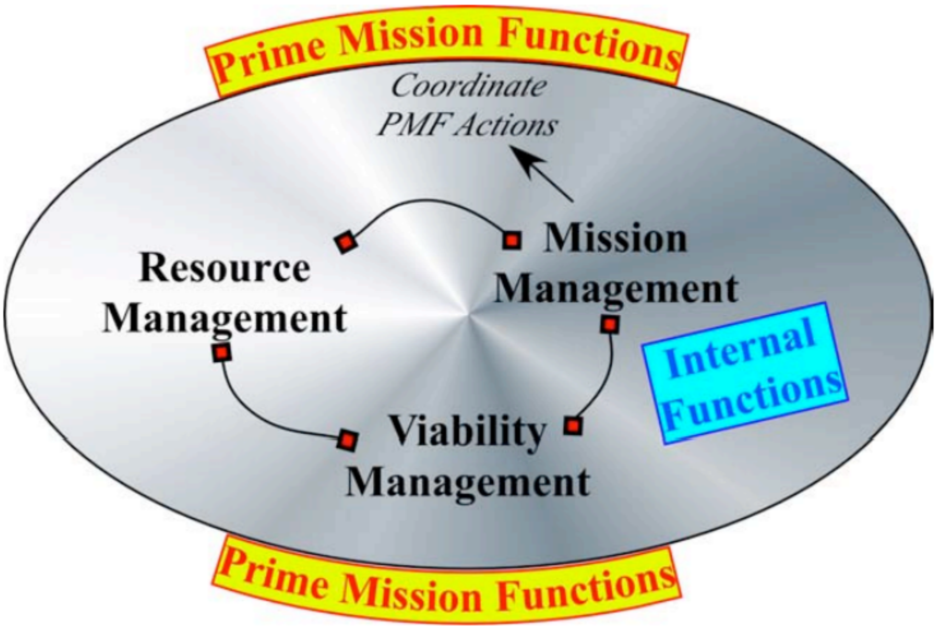


Figure 7: Relationship between prime mission functions and internal management functions.

---

[5] **Stakeholders:** those who stand to gain, or particularly to lose, from the successful completion of a project or enterprise.

[6] The conception of PMFs and internal functions is but one of many ways to formulate systems design and architecture. Systems architects may have idiosyncratic approaches.

Prime mission functions are those evident to an external observer. Internal functions are those that may be deduced to exist “within” any open system as it exchanges energy, substance and information with its environment and as it “orchestrates” PMF activities.

It is helpful to examine these internal management functions under three headings, as shown in the figure:

- **Mission management systems.** These are systems that manage, control, coordinate and deploy mission-specific functions. A weapon, or a strategy, might be mission specific, so the facilities associated with arming/delivering the weapon or coordinating the strategy would constitute mission management systems.
- **Viability (or platform) management systems.** These are systems that maintain the platform in a capable state, ready for anything, but are not mission-specific. A navigation system or a commercial department would be part of viability management suite, since these would be continually active, regardless of particular mission…
- **Resource management systems.** These are systems that acquire, distribute, supply, convert and dispose of resources. Resources include fuel and energy, consumables, payloads, finance, personnel, etc..., etc... according to system type.

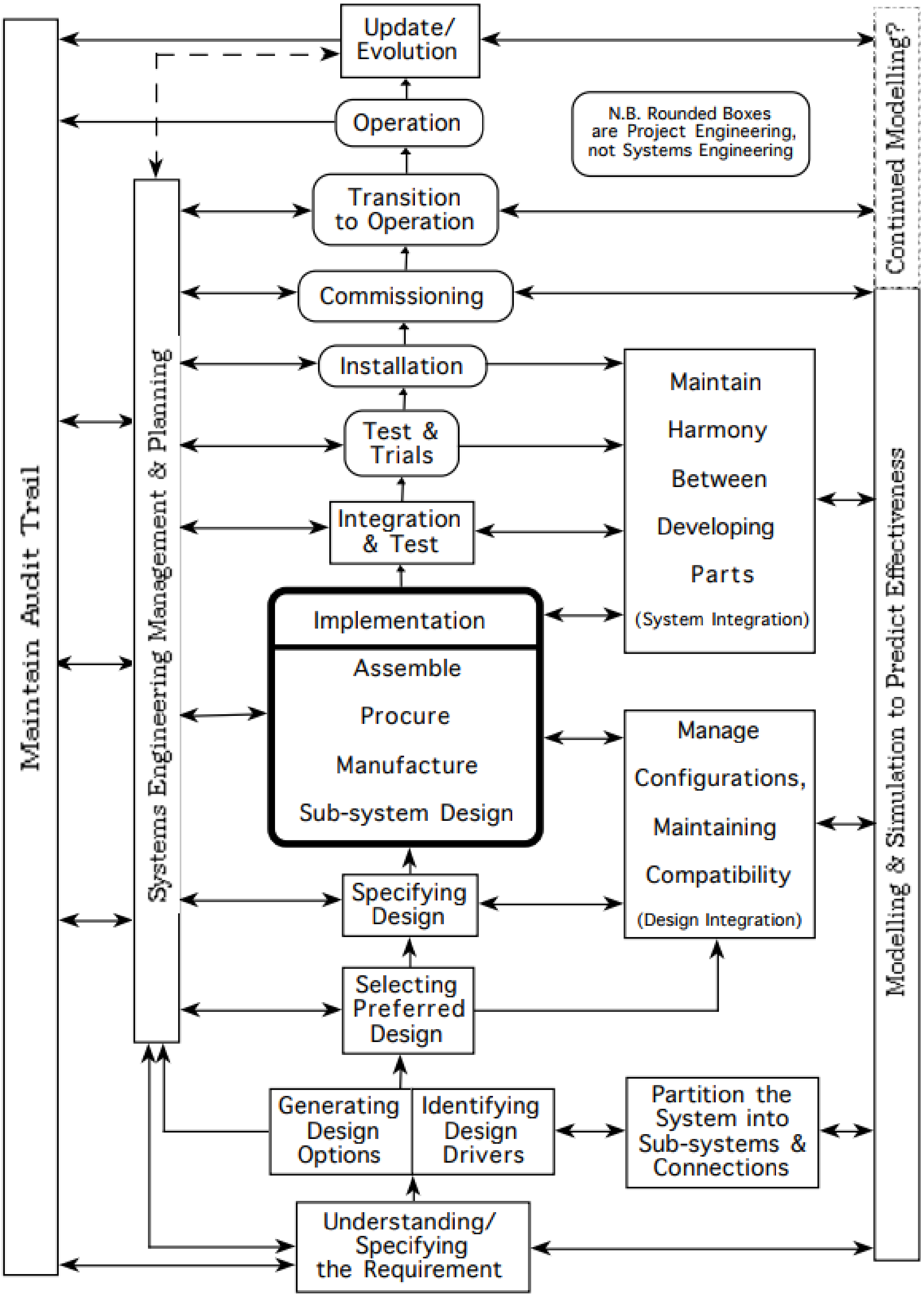

Update/ Evolution
Operation
N.B. Rounded Boxes are Project Engineering, not Systems Engineering
Transition to Operation
Commissioning
Installation
Test & Trials
Integration & Test
Implementation
Assemble
Procure
Manufacture
Sub-system Design
Specifying Design
Selecting Preferred Design
Generating Design Options
Identifying Design Drivers
Understanding/ Specifying the Requirement
Maintain Harmony Between Developing Parts (System Integration)
Manage Configurations, Maintaining Compatibility (Design Integration)
Partition the System into Sub-systems & Connections
Maintain Audit Trail
Systems Engineering Management & Planning
Continued Modelling?
Modelling & Simulation to Predict Effectiveness

Figure 8: Archetypal systems engineering plan. (Hitchins, 1992).
Round-cornered boxes are project engineering, not systems engineering.

Models of systems engineering

Classic systems engineering, mid '80s

Models of systems engineering have existed for many years; figure 8 shows a typical systems engineering plan from 1986. Figure 8 starts at the bottom with the problem (understanding and specifying the requirement) and works to the top with update or evolution — it was not assumed that the system will be replaced; instead, it may evolve and adapt in line with the changing situation and need for improved performance and effectiveness.

Returning to the start, the systems engineering problem-solving paradigm is evident in: generating design options, identifying design drivers and selecting preferred design: note, too, partitioning system into subsystems and connections, which effectively formed architecture (organicism). The plan was consistent with the understanding that systems engineering made and manufactured nothing, while engineering did indeed make, manufacture, install and commission, operate and update…

The plan was archetypal in the sense that, for any real project, the plan would be adapted/converted to serve real world situation, domain and context.

Note the continual reliance on simulation modeling to predict effectiveness, throughout; the maintenance of an audit trail, essential to accommodate customer's frequent changes of mind (often later "conveniently forgotten;") and systems engineering management & planning, which was continually revising in line with problems and progress.

Classic systems engineering organization & method

Systems engineering management followed a standard plan, of which figure 9 would be typical. The figure indicates the skills that would be required under each of the major headings. As with figure 8, the headings marked equipment engineering and software engineering were not systems engineering, per se, but engineering, to be effectively managed by systems engineering which provided the requirement specifications for, and supervised, engineering work to guard against requirement "creep", and changes to emergent properties.

Activity moved from left to right in the figure, starting with:

- **Operations analysis.** The principal output from operations analysis was the user requirement specification (URS), showing what the user needed (wanted?) in the way of facilities and capabilities to perform in his rôle.

- **Requirements analysis**, which used the user requirement specification (URS) as a principal input, and which gave, as its principal output, the system requirement Specification (SRS).
- **Systems design**, which took as its principal input the SRS, and gave as its principal output a matched set of Performance and Design Requirement Specifications (PDRs).
- These PDRs then served as the inputs to Equipment Engineering, and Softwar Engineering. In this classic systems engineering scheme, equipment1 and software were subcontracted. PDRs would be used as part of competitive tendering to select preferred subcontractors.
- Once equipments and software were engineered — or acquired — the finished products were brought together for test and integration.
- Finally, acceptance trials followed installation and commissioning…

Note the absence of project management from figure 9, which was in effect performed by systems engineering management. There is, however, a section for project support, which addressed programme, financial, data, quality and configuration management. As the work was so complex and unpredictable, systems engineering was generally contracted on a cost plus basis.

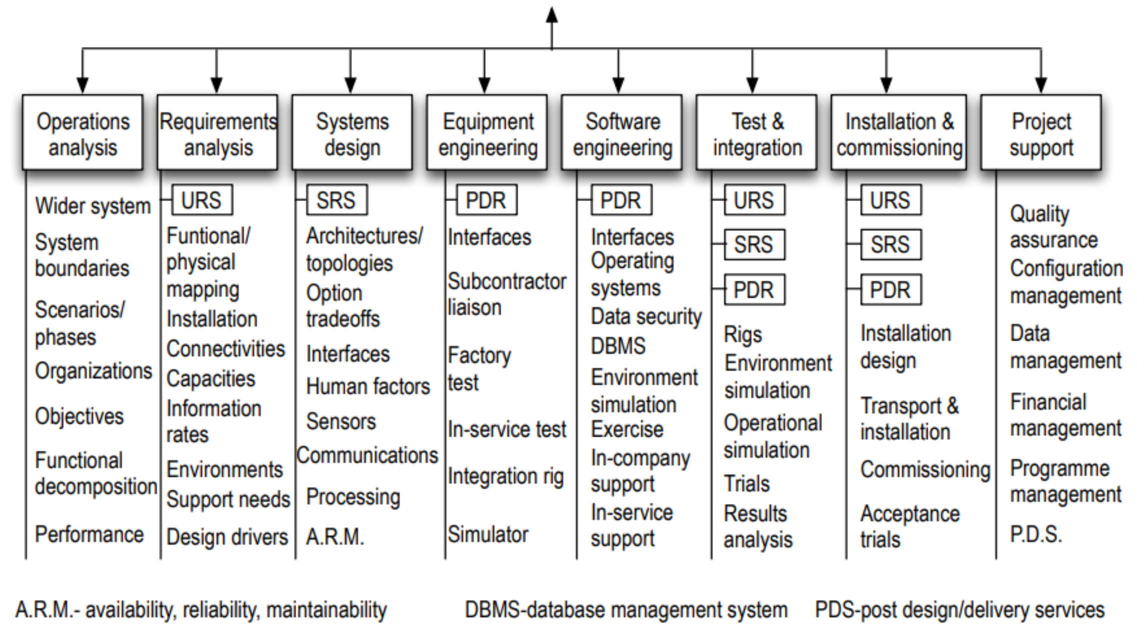


Figure 9: Typical systems engineering and project engineering skills circa 1985 (Hitchins, 1986)[7]

---

[7] Note the contemporary use of “equipments” to denote technological components, which today are confusingly (erroneously?) called “systems”.

Updating systems engineering

Since 1986, times and situations have changed. The archetypal plan of Figure 8 would no longer suffice, in particular because situations, issues and problems have become evermore complex. Major steps forward have been made in:

- Complex problem-solving.
- Dynamic simulation.
- Dynamic architecture and its impact on system performance.
- Genetic algorithmic systems design methods.
- Networking.
- Psychology and human behavior.
- Robotics.
- Understanding of deterministic chaos and self-organized criticality in systems.
- Many, many more...

The same fundamental concepts and principles still define systems engineering, however: systems engineering seeks to create an optimum (best) solution to a complex problem, employing the same principles of holism, synthesis and organicism as guiding lights. And the understanding persists, too, that complex systems exhibit emergent properties, where the whole is greater than the sum of its parts, such that emergence may offer significant advantage in performance, capability, effectiveness and affordability.

The challenges presented by complex problems were researched in the 1980s and subsequently. Systems-theoretic “soft” methods were developed, specifically aimed at “messy organizational problems”, so, dealing with groups of people as subsystems, functioning and interacting within some social system. Problem-solving methods formed around the GPSP of figure 6, a leading proponent being Checkland’s Soft Systems Methodology (SSM)(Checkland, 1981).

The GPSP also inspired a more general problem-solving methodology — the Rigorous Soft Methodology (RSM) (Hitchins, 2007), which is systems-tool supported, but which has yet to prove as popular as SSM. Combining the RSM with other systems tools and methods results in a systems methodology shown at high level in the behavior diagram of figure 10. There could be other systems methodologies, according to the particular SE paradigm considered. However, the systems methodology of figure 10 is sufficiently high level to be applicable, for example, to the continuous circular flow paradigm (Toyota style) and to in vivo systems engineering, such as that prosecuted by armed forces on land, at sea, and in the air, often in the middle of operations, and sometimes as a result of inflicted enemy damage. The ill-fated Apollo 13 mission also gave rise to some remarkable in vivo systems engineering, which resulted in the safe return of the crew after their in-space catastrophe...

Even at high level, the systems methodology reveals many aspects of systems thinking, architecting and design which were not evident in the SE plan of figure 8, including problem and solution spaces, prime mission functions (PMF), containing and sibling systems (for environment and context), concept of operations (CONOPS), functional and functional/physical architectures.

The behavior diagram of figure 10 comprises three columns: Input, function/process, and output columns. The center column shows a logical succession of functions/processes, 1 to 7, from “exploring the problem space” to “creating and proving the solution system”; these have been encountered already in figure 2. The right hand column shows the outputs, or deliverables from each process: since the processes form a logical sequence, so too do their outputs. At left are inputs, including proprietary systems methods, as listed in the inset box.

Systems methods are, by definition, methods that are problem, scale, situation and solution independent, and are therefore not inappropriate in a high-level systems engineering methodology schematic.

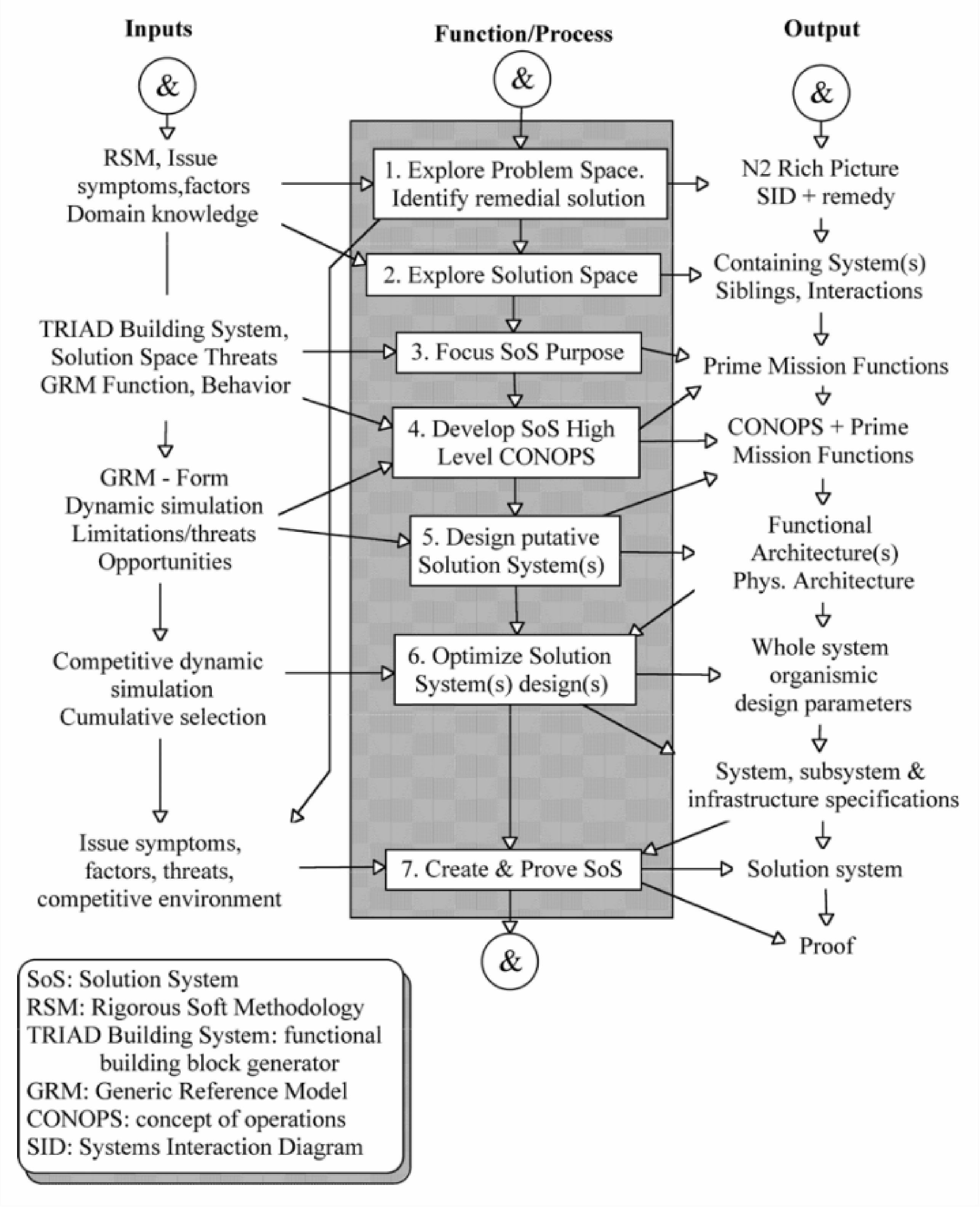

Inputs
Function/Process
Output
&
RSM, Issue symptoms,factors Domain knowledge
TRIAD Building System, Solution Space Threats GRM Function, Behavior
GRM - Form Dynamic simulation Limitations/threats Opportunities
Competitive dynamic simulation Cumulative selection
Issue symptoms, factors, threats, competitive environment
1. Explore Problem Space. Identify remedial solution
2. Explore Solution Space
3. Focus SoS Purpose
4. Develop SoS High Level CONOPS
5. Design putative Solution System(s)
6. Optimize Solution System(s) design(s)
7. Create & Prove SoS
N2 Rich Picture SID + remedy
Containing System(s) Siblings, Interactions
Prime Mission Functions
CONOPS + Prime Mission Functions
Functional Architecture(s) Phys. Architecture
Whole system organismic design parameters
System, subsystem & infrastructure specifications
Solution system
Proof
SoS: Solution System
RSM: Rigorous Soft Methodology
TRIAD Building System: functional building block generator
GRM: Generic Reference Model
CONOPS: concept of operations
SID: Systems Interaction Diagram

Figure 10: Systems engineering methodology — behavior diagram (Hitchins, 2007)

Comparing the 1986 SE plan of figure 8 with the 2007 SE methodology of figure 10, and remembering that they are at different levels vis-à-vis figure 3 (Elaborating the SE paradigm), it is evident that the systems methodology concerns itself much more with problem solving, conception and functional design, context and environment, whereas the SE Plan emphasized the management "nuts and bolts" of bringing the various parts together, making them work and proving that they perform according to design and customer expectations. In this, the SE Plan assumed that the solution system was socio-technical or technological, which would have been reasonably expected at the time.

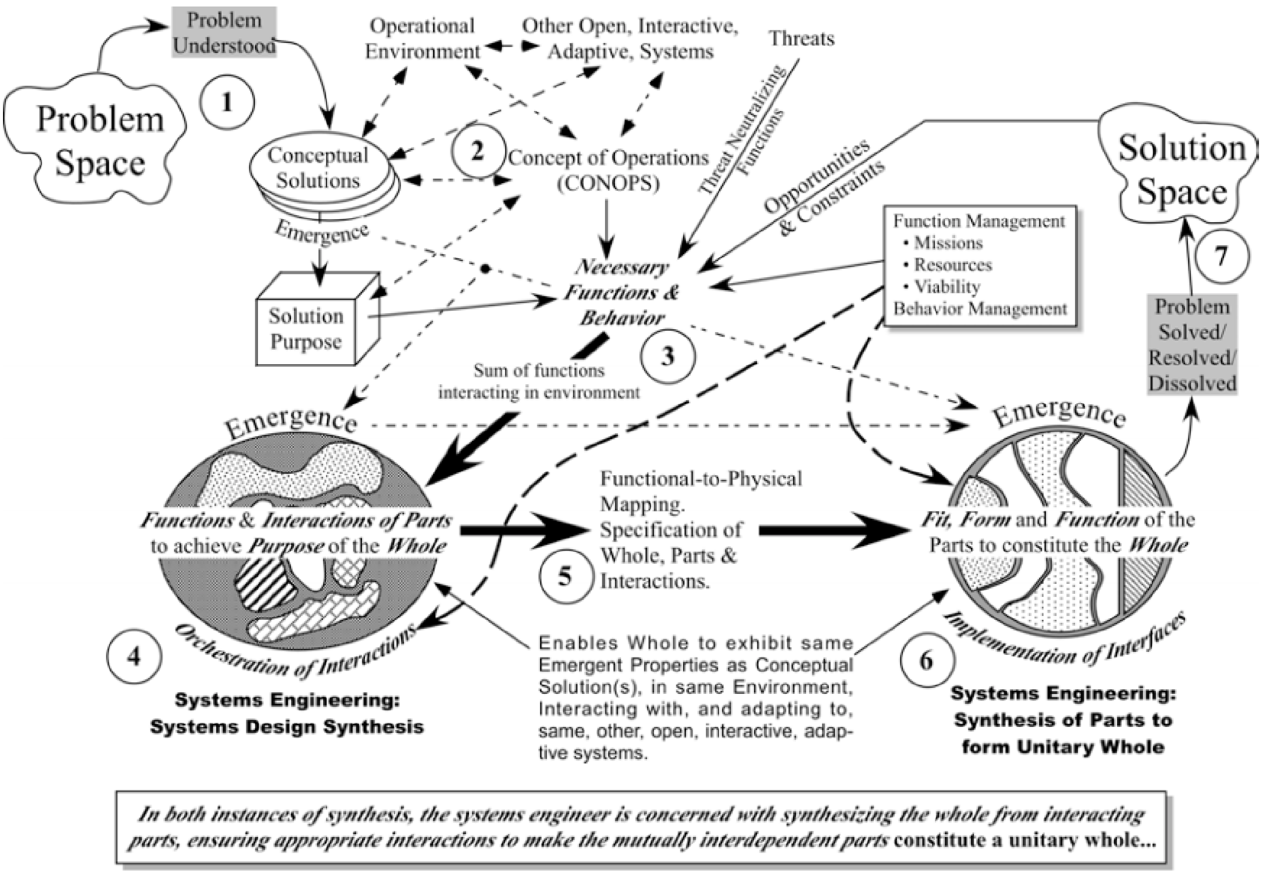

Problem Space
Problem Understood
1
Operational Environment
Other Open, Interactive, Adaptive, Systems
Threats
Conceptual Solutions
2
Concept of Operations (CONOPS)
Threat Neutralizing Functions
Opportunities & Constraints
Solution Space
Emergence
Solution Purpose
Necessary Functions & Behavior
Function Management
• Missions
• Resources
• Viability
Behavior Management
7
Problem Solved/ Resolved/ Dissolved
3
Sum of functions interacting in environment
Emergence
Emergence
Functions & Interactions of Parts to achieve Purpose of the Whole
Functional-to-Physical Mapping. Specification of Whole, Parts & Interactions.
5
Fit, Form and Function of the Parts to constitute the Whole
Orchestration of Interactions
4
Systems Engineering: Systems Design Synthesis
Enables Whole to exhibit same Emergent Properties as Conceptual Solution(s), in same Environment, Interacting with, and adapting to, same, other, open, interactive, adaptive systems.
Implementation of Interfaces
6
Systems Engineering: Synthesis of Parts to form Unitary Whole
In both instances of synthesis, the systems engineer is concerned with synthesizing the whole from interacting parts, ensuring appropriate interactions to make the mutually interdependent parts constitute a unitary whole...

Figure 11: Systems engineering — an ontology.

A contemporary SE ontology

Figure 10 presents the overall process of going from problem space to solution space as a behavior diagram. An alternative representation of the same journey is presented in figure 11 in the seven marked steps:

1. Understand the problem and develop conceptual solutions.
2. Develop one or more concepts of operations (CONOPS) in context.

3. Gather the necessary functions and behavior from the various sources shown, to create the sum of functions which would be needed, interacting in the future environment, to provide a purposeful, effective solution to the problem.
4. Organize functions and orchestrate their interactions to create a dynamic, interactive functional architecture operating and exhibiting emergent properties in (simulated?) context and environment.
5. Map functional architecture on to one or more physical architectures, specifying the whole, the parts and the interactions in solution-transparent form for acquisition or development or both.
6. Integrate the acquired parts in simulated or real context and environment, to create a whole with the same emergent properties in context as those of step 4.
7. Install, commission, etc..., the whole into the solution space as a new system, a replacement system, a reorganized system.

At each and every step, including the last one, check that the developing solution system solves the problem in context.

Summary & conclusions

Systems engineering appears founded, not in physics as one might suppose engineering to be, but in biology and anatomy, which — with their levels of organization — had previously developed a cogent approach to the accommodation and management of complexity. A biological metaphor is, then, consistent with systems engineering's: approach to complexity management; purpose in systems; and, in its unique emphasis on emergence and emergent properties.

Systems engineering has firm philosophical and systems theoretic foundations. Systems engineering incorporates fundamental principles, which — while not assuring universal success in every outcome — can afford high-integrity solutions to large-scale, complex and dynamic problematic situations and issues, where fathomable by innovative systems thinkers, architects and engineers. Ignoring such foundations prejudices successful outcome.

The first of these founding principles is holism: the theory that parts of a whole are in intimate interconnection, such that they cannot exist independently of the whole, or cannot be understood without reference to the whole, which is thus regarded as greater than the sum of its parts. Holism applies equally to the complex problem, the complex solution, to complex systems engineering-as-a-system, and is the foundation for optimization, i.e. best performance in context.

The second principle, synthesis, is the opposite of reduction. Reduction provides knowledge, of "how things work". But reduction views parts in mutual isolation, such that the effects of cooperation, coordination, synergy and context are overlooked; it is these that conspire to create emergent properties, which may be disregarded by engineers employing reductionist methods, but are fundamental to the synthesis of complex systems.

(Traditional systems engineering methods such as functional decomposition, the waterfall method and the Vee-method are reductionist, not holistic. They stem from software methods; it may be reasonable to decompose a software function into separate sub-functions, where — within the software at least — there will be no subsequent interaction between the sub-functions that may affect their respective behavior. Systems decomposition into separate subsystems is not valid, however, since the various subsystems will affect each other's respective functioning and behavior, as do the organs within the human body.

The third principle, organicism, emphasizes organization and architecture. Functional architecture is the pattern formed by mutually bound clusters of functions on one hand, and coupling between such clusters on the other (functional binding and coupling.) Architecture emerges ideally from the problem as a configuration to enhance performance, availability, survivability and security, to optimize emergent behavior/performance-incontext.

These three guiding principles are observable in "natural systems engineering", which has evolved over the last 520 million years: complex living organisms serve as metaphors for complex man-made social, socio-technical and technological systems. E.g., Nature's organisms are maximally efficient, consistent with survival. (Lotka, 1922).

Paradigmatically, systems engineering can be seen as problem solving, or perhaps as maintaining circular flow. The latter applies not only to industrial systems engineering in Japan, but also to ring-roads around major cities (London's M25, Paris' Périphérique, Washington's Capital Beltway, etc...), to airports (e.g. Heathrow, Stansted and Gatwick around London), to "ring main" systems for digital communication, electrical and water supplies, and to many more complex transport, logistical and infrastructure systems designs that have found the circular paradigm appealing, robust and practical.

Final note: The philosophy of systems engineering set out above appears at odds with some current practice. Yet, the philosophy is rational, logical, justifiable and demonstrable. Compared with some contemporary practices:

- Systems engineering is founded in systems theory and practice, and so is substantially different from multidisciplinary engineering (i.e. engineering);
- Managing complexity is "built in;" so, too are innovation and creativity;

- Orthodox hierarchy displaces the tautologically challenged “system of systems”.
- There is no mention of project management: systems management appears both necessary and sufficient.
- If the SE philosophy is to continually evolve and adapt systems to changing circumstances then there is no perceivable “end”, therefore no anticipatable system lifecycle (although there may be many technological lifecycles.)
- There has been little mention of cost. SE philosophy finds “solving the problem” to be both necessary and sufficient, and many of the finest achievements of systems engineering have not been noticeably cost-limited. Cost is principally for engineering
    - Premature consideration of cost in systems engineering can impede innovation, restrict creativity and result in ineffective, short-lived solutions that prove more expensive in the long run…
    - Contemporary emphasis on cost, performance and schedule is consistent with multidisciplinary engineering, and with the engineering of systems, but not with “systems engineering as complex problem solving”.
    - Systems design may be instantiated using many different approaches, including commercial off-the-shelf (COTS) artifacts, phased implementation, manpower in place of machines, etc...; so cost derives mainly from the different ways in which systems designs may be engineered… yet each solution may “solve the problem”.
    - However, cost can be of concern where, for instance, there is a view to optimize overall systems design for best performance in context, using e.g., cost-effectiveness (“best value of money”) as an optimizing parameter…

Finally, the systems theoretic SE philosophy espoused above — although rational and logical — nonetheless may emerge as something of a surprise. The correspondence between emergence and the management of complexity in biology/anatomy on the one hand, and man-made systems and systems engineering on the other, shown in figure 1, may appear obvious once expressed, but is neither widely appreciated nor taught.

(D K Hitchins) Monday, June 11, 2012.

References

- Ackoff R.L. and Emery, F.E., (1972) On Purposeful Systems, Aldine-Atherton, Chicago IL

- Bertalanffy, Ludwig von, (1950) An Outline of General System Theory, British Journal for the Philosophy of Science 1, p. 139-164
- Checkland, P.B., (1981) Systems Thinking, Systems Practice, John Wiley, Chichester
- Hitchins, D.K., (1986) Managing Systems Creation, IEE Proceedings, Vol.133, Part A, No 6
- Hitchins, D.K., (1992) Putting Systems to Work, Wiley and Sons, Chichester, UK
- Hitchins, D.K., (2003) Advanced Systems Thinking, Engineering & Management, Artech House, Norwood MA
- Hitchins, D. K., (2007) Systems Engineering: A 21st Century Systems Methodology, John Wiley, Chichester
- Lewin, K., (1949) Frontiers in Group Dynamics: Concept Method and Reality in Social Science: Social Equilibria and Change. Human Relations, 1, (1), 5-41
- Lotka, A.J., (1922) Contribution to the Energetics of Evolution. Proc. Natl. Acad. Sci., 8, 147-155
- Womack, James P., Jones, Daniel T., & Roos. Daniel, (1990) The Machine that Changed the World, Rawson Associates, NY

Complex social system engineering

Abstract

A distinction is drawn between:

- **Social engineering (SE)**: ideologically-influenced laws, rules, behaviours and practices of some governments and politicians, which may bear differentially upon sectors within a nation, and which organize, manage and require social behaviour in accord with some ideology.
- **Socioeconomic systems engineering (SeSE)**, concerned with the economics of resourcing complex, interacting social systems, including globalization; and…
- **Societal systems engineering (SSE)**, using systems thinking, systems science and systems methods to address and enhance quality of life and the human condition in societies.
- **Associated "measures" are those of: human capital:** an aggregate view of the human acting within economies; competencies, knowledge, social and personality attributes, including creativity, embodied in the ability to perform labour so as to produce economic value.
- **Social capital**, the expected collective or economic benefits derived from the preferential treatment and cooperation between individuals and groups.
- **The human condition**, which encompasses the unique and believed to be inescapable features of being human in a social, cultural, and personal context: quality of life; search for purpose; curiosity; thriving on new information; meaning; loneliness; freedom, and ultimate mortality.

The three complementary social practices are explored, using both modern and ancient Egyptian history as comparative backdrops to their origins, merits and limitations. Social engineering is the practice of politicians and governments, with competing ideologies currently aiming (in the West) towards greater liberalization. Socioeconomic systems engineering, resourcing viable societies, may be more scientifically based, but faces enormous complexity and risk with globalization. We humans have hardly evolved biologically over the last 80,000+ years, and we are not evolved to live in cities, which are threatening both the quality of life and — particularly — the human condition: these are the concerns of societal systems engineering. The three social practices can be seen as aspects of something greater; moreover, actions in line with

each discipline must inevitably impact upon the others. The question arises: what is this something greater?

Introduction

Investigative methodology

While humans, Homo sapiens, appear not to have evolved biologically over the last few thousand years, the societies they form and within which they live evolved significantly, such that societies in, say, western Europe or the Americas bear little relationship to societies of one hundred or one thousand years ago.

Examining social evolution is fraught, not only with practical difficulties but with sensitivities to politics, economic theories, social psychology, subjective/partisan attitudes, etc... The approach adopted in this study is to establish a baseline as reference, one where little or no social evolution had taken place, with which to compare and contrast the evolved social conditions in a modern nation state.

Ancient Egypt is selected as the baseline: it was the first ever nation state, and the first national societies arose there and flourished before there were any politics, economics, theology, sociology, etc... Ancient Egypt saw a sequence with three principal kingdoms arise, interspersed by intermediate periods of relative chaos and societal breakdown (Clayton, 1994.) The so-called kingdoms were:

- The Old Kingdom, 2686-2181BC
- The Middle Kingdom, 2040-1782BC
- The New Kingdom, 1570-1070BC

The Old Kingdom, or Pyramid Age, developed in relative isolation from external influences, and can be perceived as a natural experiment in human social development under the “controlled conditions” offered by the benign-yet-isolated environment of the Nile Valley at that time. By the time of the New Kingdom, however, Egypt was an international state, with exports and imports to and from the Levant and beyond, and was engaged in irregular armed conflict with other nations in the region. Over the period of the three kingdoms, Egyptian society may be seen as having matured or individuated (Rice, 1990) much as an individual matures from youth to adulthood.

Using the nation-state of ancient Egypt as a baseline for comparison, we may seek to contrast modern evolved social engineering, socioeconomic systems engineering and societal systems engineering with their ancient, supposedly naïve equivalents. Since modern nations vary considerably one from another, it is helpful to focus on a particular national example: the so-called parliamentary democracy that has evolved in the United Kingdom (UK) post WWII will be the principal subject in following discussions.

Instinctual human behaviours

Despite some 30,000 years or more of civilization, we humans are still subject to instinctive behaviour of the kind we can recognize in our fellow great apes, if not in ourselves… We like to think that we are civilized and sophisticated, that we can exercise "free will", and that our human behaviour is unpredictable. It may not be true.

Given knowledge of a person's background, make-up, personality and recent situation and experiences, psychologists can predict what a person will do next, and be right. We are the product of our environment, and our behaviour is the product of instinct, inheritance, experience, personality and context. (Ajzen, 1980).

The family and natural environment

Homo sapiens evolved, it seems, living in extended family groups. Extended families might number up to fifty, and hamlets or villages might comprise several extended families numbering some 250 — 500 in total; numbers are clearly imprecise. Villages were surrounded by field and forest, flora and fauna, upon which families depended fundamentally for their food resources; they evolved to live in harmony with the natural world, taking only what they needed to live while enjoying their families and their environment.

The modern "hunter and the gatherer"

Since those early times, man has not changed much under the skin. Go into a supermarket and watch women, in particular, shopping. Some appear to enter "the zone", a trance-like state in which, seemingly unaware of other shoppers, they pick items off the shelves swiftly and expertly, concentrating on items that are at, or just below, the sightline. Psychologists liken this to gathering fruit and berries off hedgerows, represented by the rows of shelves: they deduce that women instinctively collect the best, ripest fruit from just below the eye line, where it has been protected from the elements and other animals by overhanging twigs and branches — and they place products accordingly to move them off the supermarket shelves quickly, or to gain the best profit margin. It works. (Hargrave, 2005)

Men do not shop in this fashion; they are haphazard, less organized and inefficient by comparison. Men are more likely to decide beforehand what they want, go into a shop and buy it regardless of "shopping around" for the best price; they lack the gathering instinct. Consider, instead, the male business chief who stays on at work long after he should sensibly have retired, clinching deals and receiving bonuses far beyond any reasonable needs. Why? Could it be that men are reluctant to forego the hunt, the chase and the kill? Like women as gatherers, men may exhibit an instinctive "hunter" drive; which goes some way to explain their otherwise unaccountable behaviour. (Morris, 1994).

There is, then, an underlying consistency in the nature and instinctive behaviour of the intelligent, sophisticated naked ape, which may discomfort, resist, or even conflict with social engineering that seeks to modify and impose "unnatural" social behaviour, ethics and morality.

Social engineering in the UK

Social engineering is not a recent phenomenon: rulers and politicians have been social engineers since the beginning of society. The term "social engineering" acquired an unsavoury reputation in the 20th century, due in no small part to the activities of Herr Hitler, so that today's social engineers may not relish being so-called.

Today's westernized societies are becoming evermore complex, with increasing urbanization on the one hand and with greatly increased means of communication on the other, enabling the would-be social engineer to communicate with, and influence, increasing numbers of people at a time. Increasing urban complexity sets the stage for increasing pace of life and increasing, juxtaposed variety in beliefs, attitudes, cultures, ethics, morals, principles, sophistication—and dropouts, unable to maintain the accelerating pace of life. Such complexity makes it difficult to anticipate the long-term ramifications of social engineering and how one SE "experiment" may interact with another to produce outcomes that social engineers could neither foresee, nor would have happily entertained.

Politicians of all flavours are active social engineers — that is, essentially, why they are in politics. However, it also appears to be the case that they have no sound bases for predicting and anticipating counter-intuitive response from the societies they seek to engineer. Essentially, they develop, or are inculcated with, beliefs that "their way is right, will result in the right outcome, is best for the nation, etc." In democratic societies, they form parties that share beliefs, the better to dominate other parties with different beliefs… Opposing parties evolve, often to a state where successive governments are formed, essentially, from either of two parties — the two-party system — and each party pursues social engineering in line with its beliefs, only to be replaced by the alternate party, which does the same, but to alternate beliefs. Thus neither belief system (ideology) is tested for long enough for flaws to be exposed, nor are flaws traceable back to origin, being buried instead under successive layers of social legislation so that no one can be held to account, or their beliefs effectively challenged.

Should the foregoing paragraph seem unreasonable, consider the UK state education system which, pre- and post-WWII, was producing excellent scientists, engineers, physicians, but which was — in the eyes of some social engineers — failing the less able and the poor. An objective view of education then and now might perceive that the output from the state education system is significantly poorer than it was previously. In seeking to improve the lot of the poor and educationally challenged, the standards for all may have been lowered, such that we are producing fewer excellent scientists, engineers and physicians… surely not the aim of any state education system; surely not in the national interest. (Loveys, 2010: Young, 2012).

We humans are so successful as a species and are breeding and evolving socially and economically so quickly that the social engineers may overlook — or not care too much about — our humanity, our social and psychological needs, the quality of our lives and the "human condition", the subjects of societal systems engineering (SSE.) Meanwhile, Western civilization is showing distinct signs of fragmentation and degradation, even collapse in the 21st century… (Strauss, 2012).

Urbanization

Going back only some 50-60 years to the end of WWII is not enough to see when the radical changes we see in today's western society really started. For that, we may look back to the origins, in the UK, of the industrial revolution, and particularly to the mechanization of agriculture. Figure 1 tells the story, from pastoral peace at left to urban congestion at right. And all the while, as the figure shows, Homo sapiens was, instinctively, a hunter-gatherer — which behaviours re-emerged under pressure in towns and cities.

For thousands of years — since humanity moved on from nomadic hunting and gathering— people had effectively been tied to their land, their crops and their animals, their pace of life governed by the seasons. So it was in the Old Kingdom of ancient Egypt. Indeed, the pace of life for hunters and gatherers had been governed by the seasons too, but being tied to the land gave man a sense of continuity, of belonging to the land…

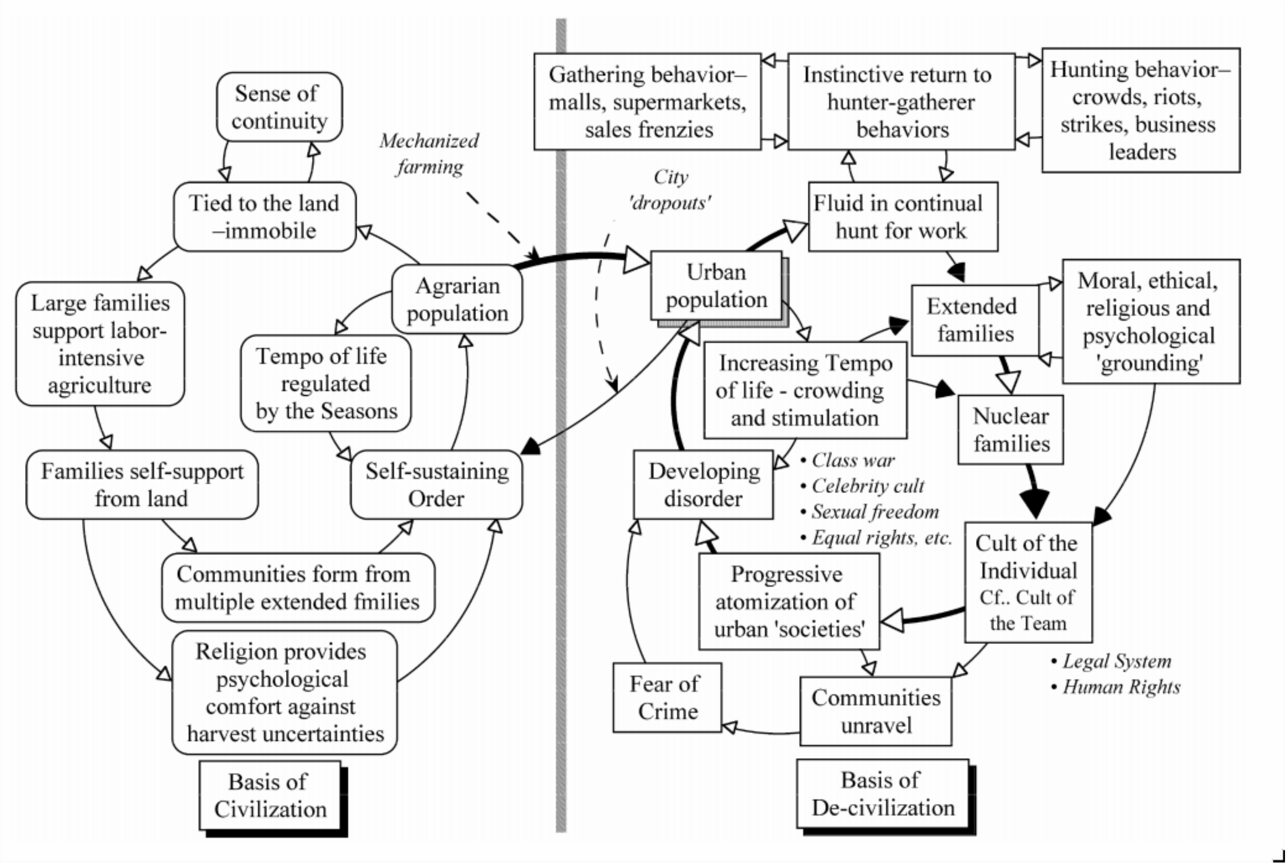

Sense of continuity
Tied to the land –immobile
Large families support labor-intensive agriculture
Mechanized farming
Agrarian population
Tempo of life regulated by the Seasons
Families self-support from land
Self-sustaining Order
Communities form from multiple extended fmilies
Religion provides psychological comfort against harvest uncertainties
Basis of Civilization
Gathering behavior– malls, supermarkets, sales frenzies
Instinctive return to hunter-gatherer behaviors
Hunting behavior– crowds, riots, strikes, business leaders
City 'dropouts'
Fluid in continual hunt for work
Urban population
Extended families
Moral, ethical, religious and psychological 'grounding'
Increasing Tempo of life - crowding and stimulation
Nuclear families
Developing disorder
• Class war
• Celebrity cult
• Sexual freedom
• Equal rights, etc.
Cult of the Individual Cf.. Cult of the Team
Progressive atomization of urban 'societies'
• Legal System
• Human Rights
Fear of Crime
Communities unravel
Basis of De-civilization

Figure 1: Urbanization — Solution or Problem? (Hitchins, 2007) Open-headed arrows indicate support, enablement and causality. Sold arrowheads indicate opposition, detraction and diminution.

When agriculture became mechanized, the unemployed land workers flocked to the towns and cities seeking work, only to find that there were many others seeking too few jobs. Slums grew up, so those who had previously been comfortable on the land became uncomfortable and disgruntled in the town.

Homo sapiens and the city

The Industrial Revolution may have been good — eventually — in socioeconomic terms, and it has raised the standard of living of the many, as opposed to the previous few. Less obvious, however, are changes in the human condition. As populations grow, towns and cities become more densely populated. Instead of living cheek by jowl with the natural world around them, people live cheek by jowl with other people, disconnected from the natural world in which they evolved… City dwellers may describe their teeming world as a concrete jungle, but it cannot be a jungle without the natural elements, other animals, forests, savannah, etc. Consider an anthropologist’s view:

> “Under normal conditions, in their natural habitats, wild animals do not mutilate themselves, masturbate, attack their offspring, develop stomach ulcers, become fetishists, suffer from obesity, form homosexual pair-bonds, or commit murder. Among human city-dwellers, needless to say, all of these things occur.
>
> “Does this reveal a basic difference between humans and other animals? At first glance it seems to do so. But this is deceptive. Other animals do behave in these ways under certain circumstances, namely when confined in the unnatural conditions of captivity. The zoo animal in a cage exhibits all these abnormalities that we know so well from our human companions. Clearly, then, the city is not a concrete jungle: it is a human zoo.”
>
> “The comparison we must make is not between the city dweller and the wild animal, but the city-dweller and the captive animal. The modern human being is no longer living under conditions natural to his species. Trapped, not by a zoo collector, but by his own brainy brilliance, he has set himself up in a huge, restless menagerie, where he is in constant danger of cracking under the strain”
>
> — Desmond Morris, The Human Zoo, 1994

In seeking to alleviate the human condition, then, the city may not be the solution: instead, the city may be seen as a virtual prison without bars. Concentrating people in cities may ease the logistics of looking after large populations, supplying food, water, power, sanitation, entertainment, etc... But, such concentrations also generate social misfits, depression, discontent, riots, pollution, crime, gangs, drug abuse, etc., all of which “products of city living” give the police more work to do — so policing is more demanding — and perhaps even “heavy handed” on occasion — in cities, while the human condition is progressively further depressed.

The media and social engineering

Many people no longer live in extended family groups, but as individuals, working perhaps in some city, remote from family, with acquaintances but few real friends. This process of creating “disconnected individuals”, social atomization, enables TV to have a magnified influence on social behaviour: it is now possible to simultaneously influence tens of millions of individuals simultaneously through the persuasive influence of the dynamic picture and the spoken word. Newspapers have a similar, perhaps less simultaneous, potential to spread doom and gloom; populist (“redtop”) newspapers in particular use sensationalist headlines to enhance circulation, regardless of the impact they might have on the vulnerable, elderly and socially isolated…

Figure 2 illustrates the supposed effect of media on social stability. Politicians use the media to propagate their political beliefs and ends. It used to be the case that the nuclear and extended family served as a calming influence, generally neutralizing the effect of social turbulence and protecting individual family members from mass hysteria as threats of new of disasters of ever greater apocalyptic dimensions were spread by populist newspapers; the unifying family belief system similarly provided a calming influence…

It used to be the case, too, that the family included “elders” with wisdom and experience who would advise, guide and restrain the more unruly, unprincipled and testosterone-driven youngsters. That too has largely evaporated with the breaking up/tearing apart of the family through social turbulence, and the advent of “social media” (e.g. Twitter and Facebook) that allow, enable and encourage the “unspeakable to foment the uneducable[8]”, with resulting antisocial youth gatherings and riots.

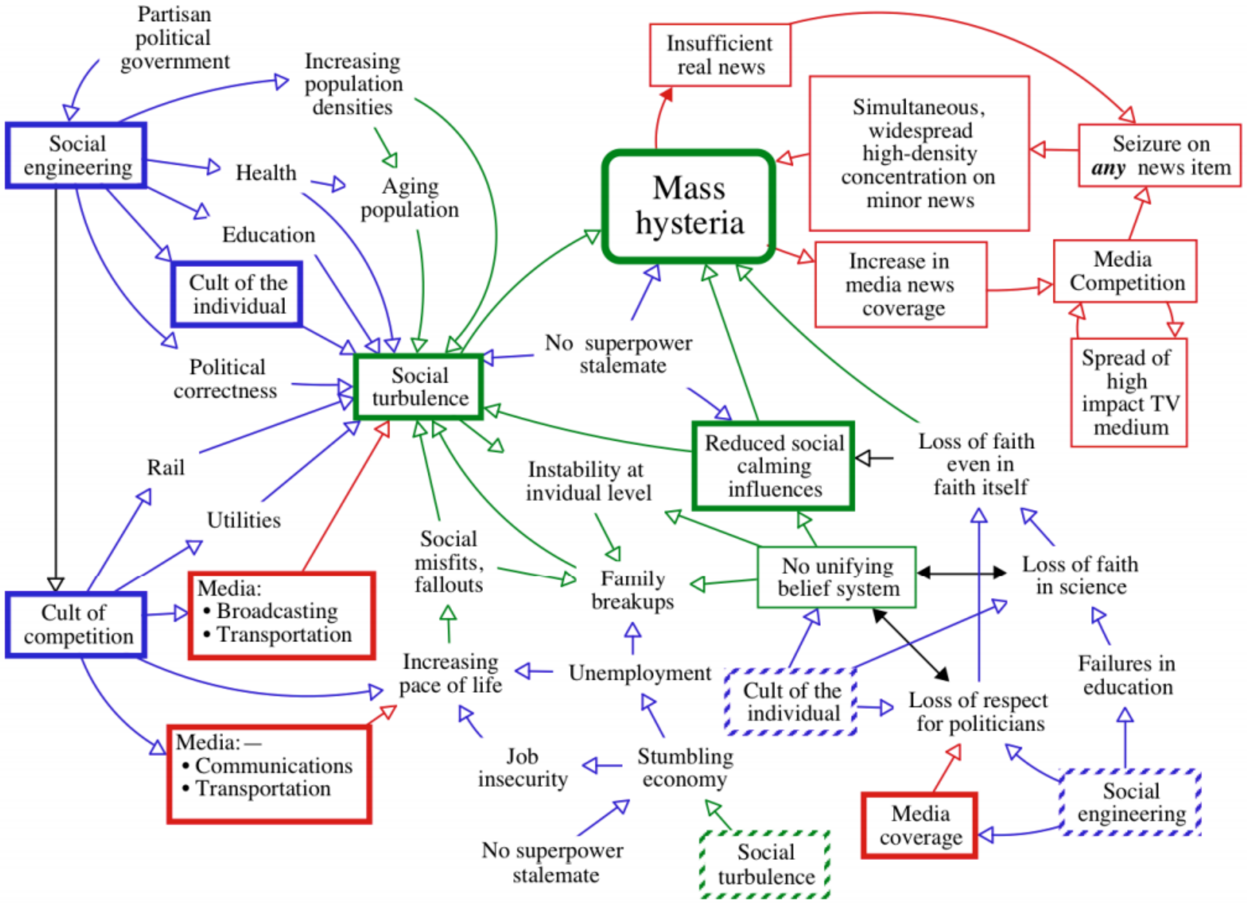


Figure 2: Social stability and the media (Hitchins, 2003) mind map — read arrows as “contributes to…”

---

[8] With apologies to Oscar Wilde.

Political correctness: an instrument of social engineering

By 1970 in the UK, New Left socialists had adopted and propagated 'political correctness.' Political Correctness (PC), with its echo of Stalinist orthodoxy (Bernstein, 1990), may be defined as language, ideas, policies, and behaviour designed to minimize offence in work, gender, racial, cultural, sexual orientation, beliefs, ideologies, disability, and age-related contexts. Underwritten by social legislation, PC seeks to engineer speech and social behaviour, i.e. to control and restrict freedom of the majority to avoid potentially offending various minorities — which may be seen as reasonable on the one hand, yet prima facie, undemocratic on the other…[9]

PC raised, and continues to raise, the most profound opposition:

> "What Americans describe with the casual phrase… political correctness is the most intolerant system of thought to dominate the British Isles since the reformation."
> — Hitchens, 1999

Right wing politicians, preferring to be politically incorrect (PI), promoted the "cult of the individual", some suggesting that there was no such thing as society, only individuals. Socialist PC has persisted, however, permeating all corners of UK society, along with not unrelated Health & Safety legislation, leading to a national Risk-Averse Culture, and associated Compensation Culture, stimulated by the advent of solicitors advertising "no win, no fee" services in the media. These three, together, have had a deleterious effect on the human condition: they restrict freedom of speech and action, obstruct purpose, curiosity and creativity, and so aggravate the human condition:

- Teachers and youth leaders stopped "risking" outdoor activities.
- Schools stopped "risking" practical science experiments.
- Schoolchildren were banned from such dangerous practices as playing conkers and hand standing in playgrounds (sic).
- Parents were prevented from videoing their children in nativity plays. Photographing children in swimming pools, and learning to swim, were banned.
- And so on…

As with Prohibition of alcohol in 1920s USA, people reacted predictably by creating replacement expressions for the "politically unacceptable", while politically incorrect behaviours have been driven underground, not eradicated. At the same time, as though to challenge PC, the overt use of "four-letter words" has become commonplace on broadcast TV, in apparent contravention of the 1986 Public Order Act and to the disgust of many older viewers, offended by such language in their own homes; somehow this is seen as politically acceptable, while socially unacceptable to many…

---

[9] Inevitably, PC is reminiscent of George Orwell's prescient, dystopian novel 'Nineteen Eighty-Four,' with its English Socialism (IngSoc) and Thought Police (thinkpol.) (Orwell, 1949)

PC promotes the use of euphemisms to describe people. A short person is “vertically challenged”, which could also apply to a tall person. A blind person is “visually impaired”, which could also mean shortsighted, long-sighted, astigmatized, colour-blind, with cataracts, etc., so is vague, inaccurate and dubious. A fat person may be “gravitationally challenged”; which some might deem more offensive than “fat”.

A so-called euphemism treadmill developed in the US, e.g. Negro, Coloured, Black, Afro-american, and African-American, all to describe a black person.[10] Meanwhile, banned expressions remain in use by the social groups on whose behalf they had been outlawed: African-Americans may still refer to each other jovially as “niggers”; lesbians may continue to call each other, less jovially perhaps, “dykes”; although neither expression has ever been in polite general use.

Gender-neutral terms were introduced: chairperson in place of chairman; postal operative instead of postman; sanitation operative instead of dustman; actor instead of actress. The last is a peculiar affectation, which seemingly denies actresses as women, suggesting a perceived sense of inferiority vis-à-vis male actors.

There is a strong PC drive for male/female equality, overlooking their evident biological and psychological complementarities. Stimulated by this equality attractor, women seek to box and to fight in the military teeth arms, e.g. the infantry. There are calls for more women in science and the boardroom, although women may prefer to look after their growing families (Moyer, 2012). Curiously, however, there are no calls for united male/female competitions in golf, tennis, weightlifting, skiing, gymnastics, athletics, football, swimming, diving, etc., etc. Males and females are only equal, it seems, when it politically suits the social engineers…

As an instrument of Social Engineering, Political Correctness has had a counter-intuitive effect on UK society: in seeking not to offend different social minorities, many of which may not have been offended in the first place, PC has managed to seriously prejudice freedom of speech and action, constrain liberty and afflict the human condition of most, if not all, of the population.

Progressive degradation

Looking at the various social influences (media expansion, marginalizing of Christianity, political correctness, compensation culture, etc.) individually, it may seem that each is a passing issue, and that society recovers in time. And it appears to be the case that society at large is resilient, i.e., left to its own devices, it will stabilize, or at least calm down. Looking over, say, the last sixty or seventy years, on the other hand, it is possible to detect a continuing trend in which "the human condition" has been progressively prejudiced — see figure 3.

---

[10] Using the same ‘logic,’ and since all Homo sapiens are believed to have originated in E. Africa, people in the UK would be African British? How would a white boy from S. Africa be described in the US?

In some measurable respects, the human condition in the UK has clearly improved, notably in terms of health and, recently, in longevity. That advance is threatened by the wave of obesity that is sweeping over the western world, and by increased and irresponsible bingeing on alcohol, leading to an alarming increase in liver failure in younger people. Obesity appears to stem from an environment where food is abundant but where regular physical exercise is not…(Hill & Peters, 1998). The causes of youthful, alcoholic binge drinking are more difficult to discern, but may be associated with "coming of age" rituals of long standing, where young people are deemed socially and legally responsible for themselves and no longer under parental control, setting the stage for a so-called "party culture", where alcohol is freely and cheaply available.

As figure 3 illustrates, State Welfare addresses many more aspects of social life than was anticipated by its original architects. While the social benefits of State Welfare might seem obvious in the abstract, those supposed benefits might not have accrued in practice. Some negative effects are shown in the figure: there are others. For example, today, presumably as always, an intellectually stimulating, nurturing and physically safe family, with both parents, is important to the upbringing and well-being of children. A recent comparison between two nations (UK & US), with and without significant State Welfare, shows that Welfare cannot compensate for the absence of one parent, having a stepparent, etc..: for reasons that are unclear, the effect is most marked with boys. (Parcel, 2012.) Counter intuitively, such studies suggest that provision of State Welfare, far from alleviating the human condition, may be aggravating it…

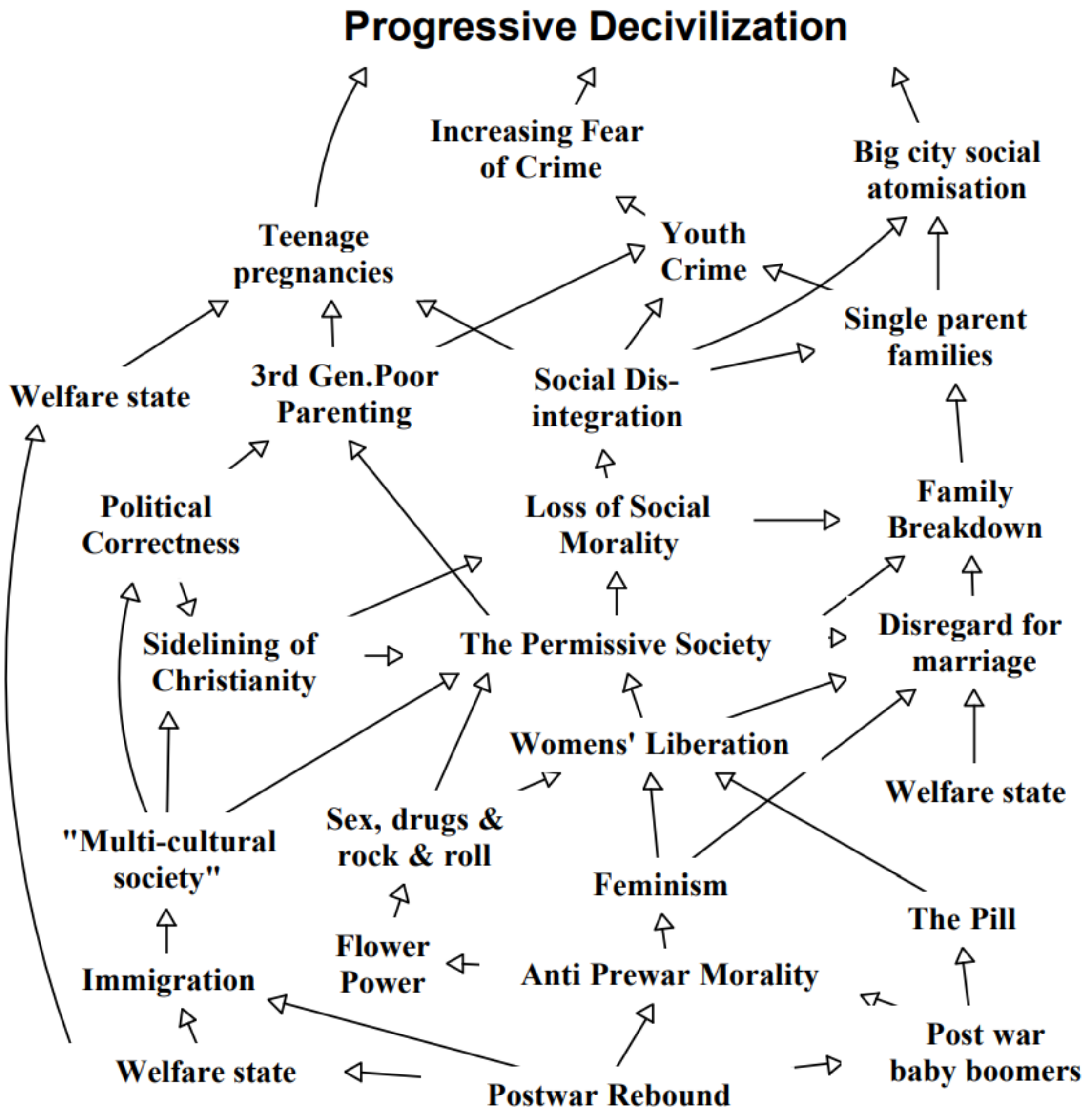


Figure 3: Diminishing the human condition: UK 1945 — 2012 attribute enhancement structure: read arrows as: “contributes to, helps to achieve”.

Part of the human condition must concern security, freedom from fear, and contentment: those feelings were significant during the fifties and early sixties. In the 1950s, children sported scabs on arms and knees as a badge of honour: children wandered freely in woods, fields and parks, enjoying total freedom, often all day. And there were no mobile phones with which parents could check up. Today’s parents are loath to let their children out of their sights for fear of abduction or worse. So, whence the latter day fear?

In earlier times, pre- and post-WWII, innate honesty of one’s neighbours was taken for granted. Except in big cities, people left their doors open, without any feeling of insecurity. If someone found money in the street, they would take it to the nearest bobby — and there would be a bobby, too, at a nearby crossroad, or junction. He would be a friend, and children would be taught to take lost property to him, ask him the time, or for directions. Nowadays police rarely patrol alone, nearly always in pairs for fear of being attacked, and rarely amenable to being addressed. And when a vehicle recently ran into a jeweller's shop window, local people vied with each other to steal the jewels fo the smashed window… what has happened to make the population at large so antisocial, risk-averse, litigious and compensation-conscious in such a short time?

Old kingdom societal and cultural development

The 4th Dynasty of ancient Egypt (2575-2465 BCE) was later to be revered as a "Golden age" it was during this time that the principal pyramids were built, including Khufu's Great Pyramid at Giza. We may learn from their society and socio-economics, which were devoid of politics, economics, logistics and democracy as such — these had yet to be conceived.

During this Pyramid Age, there was no money: trade was through barter. Yet there was a robust "widget" economy; many of the things that were manufactured were for worship of deities— pyramids, sarcophagi, temples, statues, images, etc. There were, however, food markets, bakers, brewers, potters, weavers, miners, flint-knappers, tailors and dressmakers, makers of farming implements, chandlers, ropes and boat-builders. There may not have been roads as we know them, but the River Nile provided an effective highway, allowing trade between settlements along the river. The economy could also be described as having a gross domestic product, and there were imports and exports.

Figure 4 shows the basic ideas of a barter-based socio-economy in the form of a causal loop Model. Prosperity depended upon the Inundation of the Nile, which flooded annually in July, covering the land with fine, rich, black silt. The people had learned to work together to build irrigation systems and to prevent the water from running off the land when the river subsided, resulting in a uniquely rich growing environment of hot sun, high humidity and rich, irrigated soil. Social development and socio-economic well being seem to go hand-in-hand, each promoting the other…

Cooperation among the farming people to conserve the Nile floodwater with its rich, lifegiving silt seems to have been the start of, and basis for, social development. With care, and a good Inundation, farmers could get up to three harvests a year from the land, giving them so much food resource that they had time for leisure pursuits and for thinking— especially about what would happen if the Nile Inundation should fail. From this appears to have stemmed much of their spiritual activity, praying and offering to their god king to intercede with the gods in the heavens to ensure a good Inundation. Farmers donated food to landowners who founded temples, and supported craftsmen who could fashion religious artefacts, statues, paintings, murals and burial places of outstanding beauty and purity. Landowners in turn paid taxes (principally food and clothing) to the king, who distributed this accumulation of “wealth” to establish temples, to instigate new drainage and irrigation schemes, and to run a bureaucracy of officials who travelled up and down the Nile, taking stock, adjudicating disputes, administering the law, and generally maintaining the integration of the unified state.

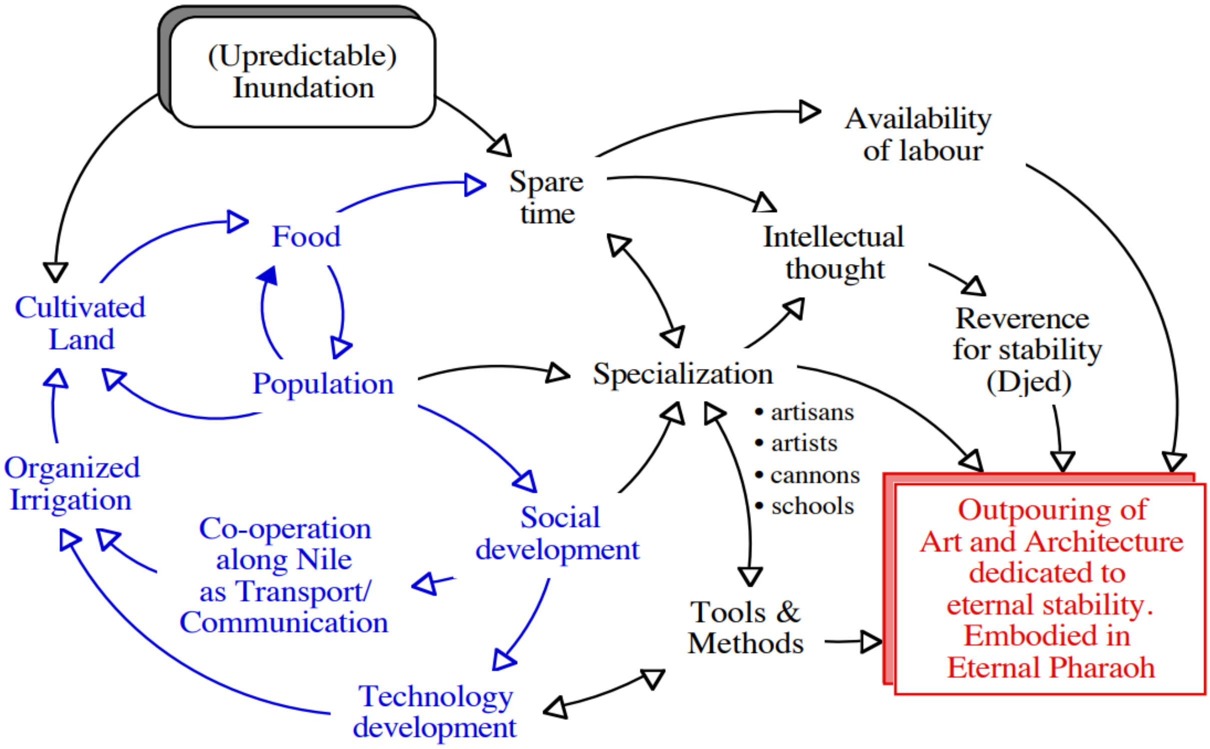


Figure 4: Old kingdom social and cultural development
Causal loop model: read arrows as “causes, leads to…”

King Snefru (2613–2589BC), and his son King Khufu (2589–2566BC) together built the greatest pyramids of the age (Clayton, 1994). Contrary to Hollywood myth, the people who built these phenomenal structures were not slaves, but intelligent people who acted out of motivated self-interest. It was their belief that, if they could provide an enduring resting place for their god-king, he would be able to intercede with the other gods in the heavens to ensure a good Inundation of the Nile on which their crops, and the welfare of Egypt, ultimately depended. King Khufu is known to have looked after the pyramid builders very well, providing them with the best food, clothing, accommodation and beer — water was too impure to drink.

With wealth largely consisting of perishables — grain, meat, vegetables, fruit, linen, etc.— there was no real basis for hoarding and accumulating wealth. The Egyptians' ability to

store foodstuffs appears to have been limited: famine was an irregular visitor to ancient Egypt. The king did what he could by diverting surpluses from one part of the two lands to relieve shortages in other areas: he could do this only if he maintained central command, control and communications up and down the length of the Nile.

Initially, the god-king was the only one who could look forward to eternal life. During the 4th Dynasty, however, the god-king granted eternal afterlife to the nobles, including the many nomarchs (provincial governors). This benevolent (democratizing?) act by the king was to be the inadvertent undoing of the Old kingdom… In the event, the kings of the fourth and fifth dynasties ceded too much power to their nomarchs, who set themselves up as hereditary regional rulers, with their own priesthoods, temples and authority.

At which point, the Old Kingdom became moribund: not long after, it collapsed into disorder and chaos following a succession of poor Inundations: internecine conflict broke out between the various nomarchs as they scrabbled for resources… Without his previous central command and control, the king was unable to maintain order, unable to share food between those with plenty and those with nothing. Which may serve as an object lesson today in breaking up countries and organizations into independent parts: this may seem ideal when times are good, but when times become hard, the weaker, resource-constrained parts will be exposed and — without friends — may go to the wall…

From ancient Egypt we may learn that socioeconomic systems engineering (SeSE) is less about money and more about maintaining centrally the power to acquire, manage, control and distribute essential resources at a national level. Power may be delegated from the centre, provided that the centre retains the right — and ability — to overrule and refocus the power centrally to distribute resources in times of trouble, threat or wrongdoing. We may also note that social order and national unity depend, fundamentally on the continuing provision of resources for the population…

The ancient Egyptians also broke the cardinal rule: population rose in times of good Inundation to be much greater than could be supported in times of poorer Inundation. The results were irregular famines, each succeeded by a regrowth of population to contribute to a new famine in a repeating cycle. To be fair, the population had little control over the situation, but the lesson is evident…

Summary: Figure 3 shows graphically how (some of) the many and various social movements and political dogmas have interacted, effectively to diminish the average human condition and to reduce the level of civilization in the UK. Each of the various movements can be seen as progressive and liberalising, even admirable, on its own. However, none has been "on its own;" instead they have acted and interacted in largely unforeseen ways. Yet liberalisers continue to call for ever more "liberalising", and so-called equality, seemingly unaware of, or disinterested in, the progressive dereliction of the human condition, and effective reduction in liberty and quality of life, that social engineering and its weapon of choice, political correctness, have already engendered in the cities (Morris, 1994).

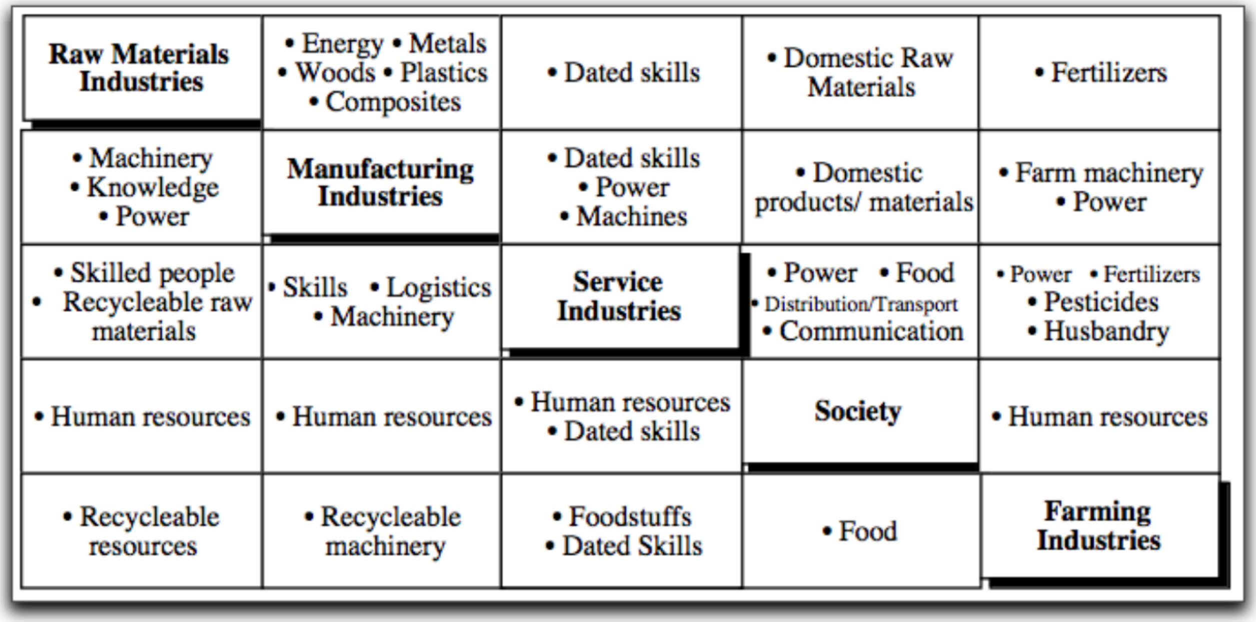
In stark contrast, Figure 4 shows how society "bootstrapped" on the back of the uniquely rich, isolated, natural Nilotic environment to create a vibrant society and culture capable of producing structures such as the Great Pyramid of Khufu at Giza that our modern civilizations, methods and tools would be hard put to equal. It would be difficult to separate out the social from the economic development; they appear closely intertwined. However, this Golden Age coincided with a strict social class structure, little if any social mobility and without any vestige of democracy. It is noteworthy that this situation persisted so long as the Nile Inundation continued to create the rich farming environment on which they all depended: social harmony, it seems, may have been founded in a plentiful and creative environment; when famine arose, social harmony broke down…

Socioeconomic systems engineering (seSE)

Socioeconomic systems engineering (SeSE) is concerned with the relationships and interactions between (e.g.) raw materials, manufacturing, service and farming industries in particular, and society in general in creating, sustaining and enhancing the national wealth, in its broadest sense. Initially addressing discrete nations, socioeconomic systems engineering may now address groups of nations and the global community of nations as they interchange people, finance, goods, information and energy. Socioeconomic systems engineering is much in demand to cope with contemporary pressures of economic downturn and globalization. The latter suggests that there are limits and precautions that any sensible nation should be taking to anticipate foreseeable issues…

Overview of contemporary SeSE

Chart 1: N2 Diagram showing typical National Socio-Economy (Hitchins, 2003).



Raw Materials Industries	• Energy • Metals • Woods • Plastics • Composites	• Dated skills	• Domestic Raw Materials	• Fertilizers
• Machinery • Knowledge • Power	**Manufacturing Industries**	• Dated skills • Power • Machines	• Domestic products/ materials	• Farm machinery • Power
• Skilled people • Recyclable raw materials	• Skills • Logistics • Machinery	**Service Industries**	• Power • Food • Distribution/Transport • Communication	• Power • Fertilizers • Pesticides • Husbandry
• Human resources	• Human resources	• Human resources • Dated skills	**Society**	• Human resources
• Recyclable resources	• Recyclable machinery	• Foodstuffs • Dated Skills	• Food	**Farming Industries**

Chart 1 is an N^2 ("N-squared") chart for a typical nation in relative isolation i.e., exports and imports are not shown. The leading diagonal shows the main societal systems:

- Raw materials industries;
- Manufacturing industries;
- Service industries;
- Society at large;
- Farming industries;

Other rectangles show the interfaces between these main systems, i.e., what each passes to the others. So, raw materials Industry passes energy, metals, woods, plastics and composites to manufacturing industries; it also passes fertilizers to farming industries. Similarly, farming industries pass food to society, and recyclable machinery to manufacturing industries. Energy is expended, work is done, and money changes hands, in transferring people, things and information between and within societal systems.

Socioeconomic systems engineering (SeSE) can be seen as the organization and management of the national system represented by chart 1, to ensure that resources required by any one sector are made available in the right quantity and quality, and on schedule from the other sectors. The whole system will exhibit emergent properties of human capital and gross domestic product (GDP): provided the population is supportable by the national assets, both of these may be expected to progressively increase…

Examination of chart 1 will show that each of the main societal systems provides what the others need and receives from the others what it needs. In principle, the N2 chart could represent a stable, self-sustaining socio-economy. A closer look would suggest, however, that there are internal dynamics to consider: what is transferred has to be sufficient to meet the needs of the recipients year round, in good and bad years; if it is, then the socio-economy may be self sufficient and self-supporting.

Overview of globalization

Potential shortfalls or excesses in capability and resources result in imports and exports of people, services and things. So, the simple N2 of Chart 1 can be seen against a quite different backcloth as shown in figure 5, again a simplification.

Here, different N2 charts for various regions have been superimposed on a global map, and interconnected. There could be one N2 chart per nation, or even one per region in some nations, resulting not in six as shown, but in hundreds. Envisage a super N2 chart where the leading diagonals are made up, not from societal systems, but from socioeconomic N2 charts. The interface rectangles would then show the various imports and-exports around the globe. Such a figure would be exceedingly complex: but then, so is the global socio-economy it would purport to represent. Such a representation in full may be impractical, but even the concept serves to show the burgeoning complexity brought about by so-called globalization.

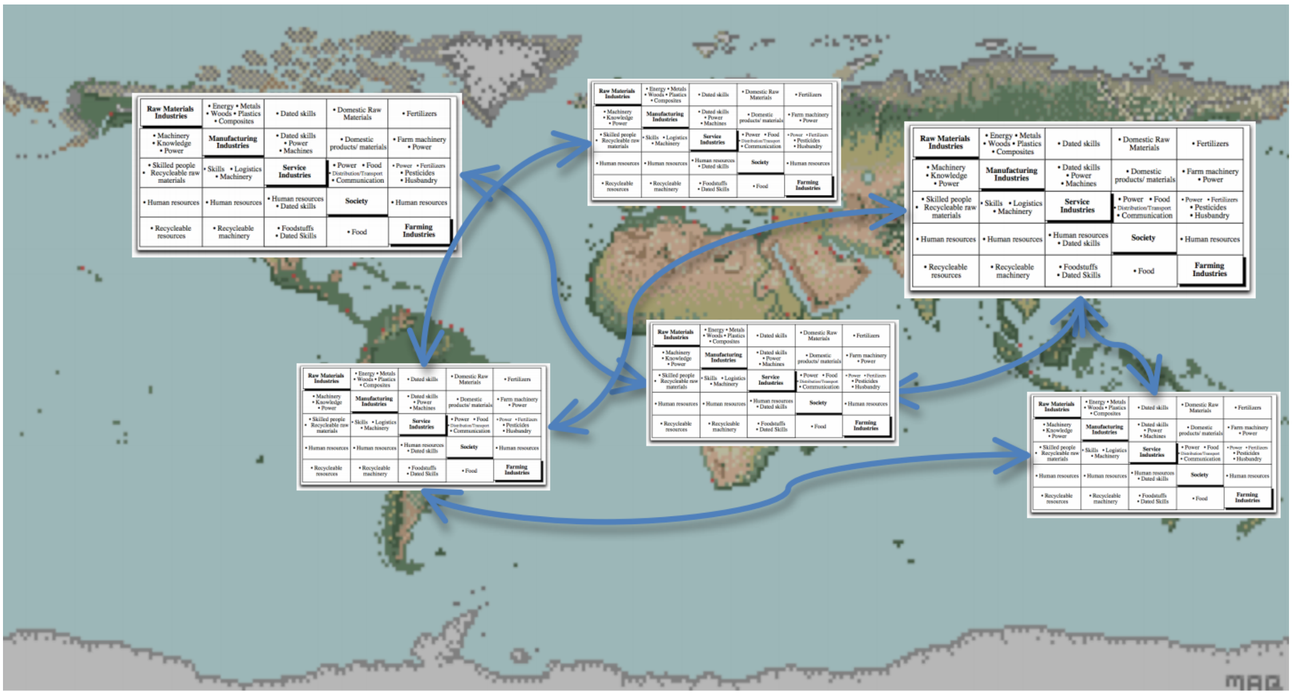
Globalization may be seen as socioeconomic systems engineering on the grand scale, and is highly complex. We may begin to glimpse the issues by considering a global socioeconomic system that is initially in a state of dynamic equilibrium when it is disturbed in some way. Le Chatelier’s Principle is relevant:

> “When a constraint is applied to a system in dynamic equilibrium, then, in so far as it is able, the system will adjust itself so as to oppose the constraint, and in so doing will move to a new point of dynamic equilibrium.”

The principle suggests, conceptually, that the complex global socioeconomic system may be able to ‘ride’ localized disasters. The Principle says nothing about the manner of adjustment, nor about the condition of the new dynamic equilibrium; for a complex system, these may not be knowable. Constraints may arise in many forms: global warming; natural disasters; war, famine and pestilence, oil shortage, lack of potable water… Neither does the Principle address the energy/work/finance needed to maintain the interchange between all of the systems, which may — in the case of globalization — prove a limiting factor…

In the light of Le Chatelier’s Principle, a globalized socio-economy is hoped to result in a robust, dynamically stable overall system, and systems theory does point in that direction; yet disturbances may not favour individual nations, and the output from large dynamic economies may well shift the point of dynamic equilibrium, to the detriment of less robust nations. Globalization smacks of a multicultural macroeconomic social experiment, with room aplenty for disasters along the way…

Chart 2 shows a greatly simplified, but still complicated, interchange between only two nations, regions or states: each is represented by its respective N2 chart, and in addition interfaces are shown for exports from the top-left nation, A, which appear as imports to the bottom right nation, B — and vice versa. Evidently there are few exchanges.



Raw Materials Industries	• Energy • Metals • Woods • Plastics • Composites	• Dated skills	• Domestic Raw Materials	• Fertilizers
• Machinery • Knowledge • Power	**Manufacturing Industries**	• Dated skills • Power • Machines	• Domestic products/ materials	• Farm machinery • Power
• Skilled people • Recyclable raw materials	• Skills • Logistics • Machinery	**Service Industries**	• Power • Food • Distribution/Transport • Communication	• Power • Fertilizers • Pesticides • Husbandry
• Human resources	• Human resources	• Human resources • Dated skills	**Society**	• Human resources
• Recycleable resources	• Recycleable machinery	• Foodstuffs • Dated Skills	• Food	**Farming Industries**

Figure 5: Global socioeconomics.

So, Nation A, top left, exports fertilisers — top right rectangle of diagram — to Nation B's farming industries. Nation B sends university students to (a presumed) university in Nation A's Service Industries; these students may return later as graduates to Nation B's Manufacturing Industries; and so on… Each nation supplies food to the other's society, although the chart gives no clue as to what kind of foodstuffs and how much. In such situations, money is the lubricant that oils the wheels of exchange, although barter is not unknown at international level, and oil is sometimes used as currency.

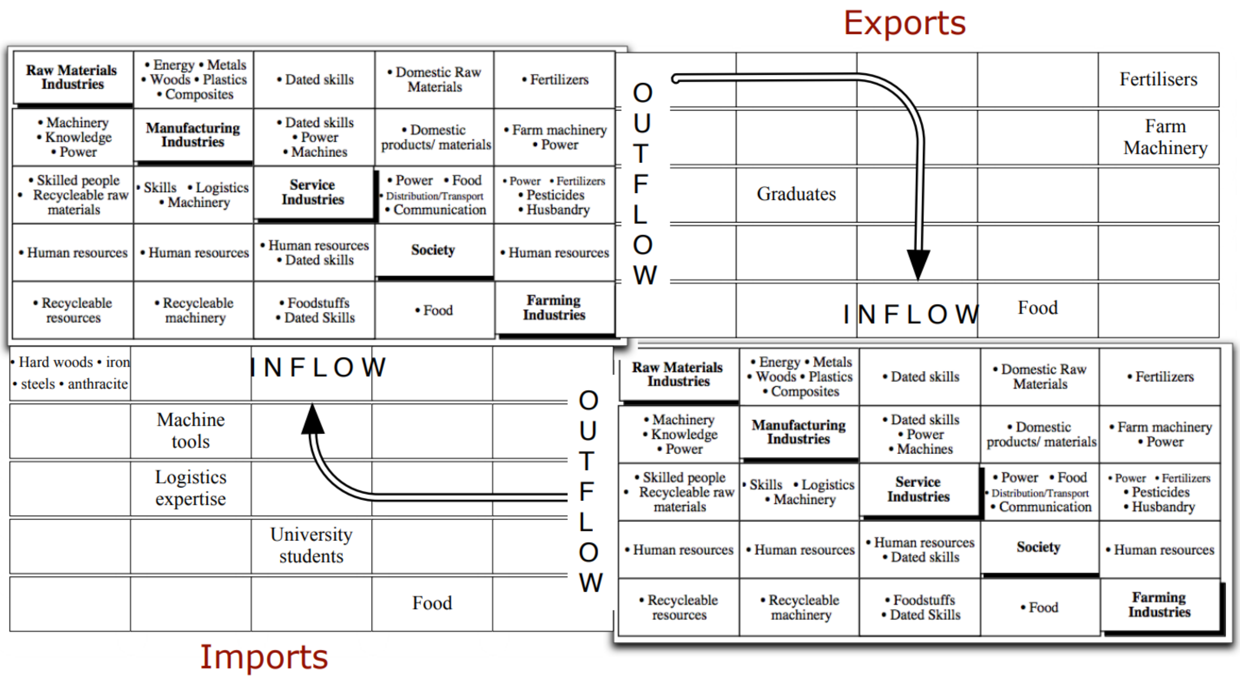
From such considerations it may be possible to estimate each nation's GDP and the balance of trade between Nations A and B. Returning to figure 5, however, and scaling up to hundreds of nations, it may prove more challenging when there are many nations involved, and when commodities pass through some countries on their way to a third party. E.g., if trade balances are out of line, if some countries are effectively “cooking the books”, it may take some considerable time for such inconsistencies to be detected.

With potential disasters in mind, there may be precautions that any individual nation might take. If, for instance, global interchange of foodstuffs were to break down, then it would behove any nation to be able so support its population from home grown food all year round. It is surely axiomatic that:

> “The population of any country or region should not exceed its indigenous capability to feed that population”

Where a country produces more than it needs for its own population, then it is reasonable and sensible to export the surplus — but not, as we have seen by Egyptian example, to increase population to consume that surplus. And it is not unreasonable to exchange surpluses in some commodities for shortages in others, provided the axiom stands.

Chart 2: Two nation interchange


Exports
Raw Materials Industries
• Energy • Metals • Woods • Plastics • Composites
• Dated skills
• Domestic Raw Materials
• Fertilizers
• Machinery • Knowledge • Power
Manufacturing Industries
• Dated skills • Power • Machines
• Domestic products/ materials
• Farm machinery • Power
• Skilled people • Recyclable raw materials
• Skills • Logistics • Machinery
Service Industries
• Power • Food • Distribution/Transport • Communication
• Power • Fertilizers • Pesticides • Husbandry
• Human resources
• Human resources
• Human resources • Dated skills
Society
• Human resources
• Recyclable resources
• Recyclable machinery
• Foodstuffs • Dated Skills
• Food
Farming Industries
OUTFLOW
Fertilisers
Farm Machinery
Graduates
INFLOW
Food
• Hard woods • iron • steels • anthracite
INFLOW
Machine tools
Logistics expertise
University students
Food
OUTFLOW
Imports

Where, however, the population exceeds the indigenous food supply, then — in the long term — either the population should be reduced or the indigenous food supply should be increased — there is no sensible future on an increasingly overcrowded planet for nations to be in permanent receipt of food aid.

With such a potential complex global socioeconomic super-system, the question arises: is globalization the result of scientific investigation, with reasonable predictions of likely behaviour and outcome, based on some robust global socioeconomic model, and with contingencies to accommodate counter-intuitive out-turns, or is it founded on the belief of politicians, and if so, who’s?

Summary: Modern socio-economies such as the UK are robust and effective, with the ability to ride poor seasons and to gather foods of all kinds from different parts of the world. In comparison, the Old Kingdom of ancient Egypt was quite unable to accommodate poor Inundations and their burgeoning population was kept in check by famine so that, perforce, they lived in balance with their environment. One issue was their inability to store and share resources between different regions, which had become semi-independent and out-of-control… Globalization could, potentially, create a not dissimilar situation between many nations.

Societal systems engineering (SSE)

Social engineering (SE) takes an agnostic, materialistic, multi-cultural, partisan stance without significant regard to the cultural and spiritual well-being of societies within the population. Yet these very senses of contentment, confidence in the present and hope for the future, may be the hallmark of a vibrant society.

Socioeconomic systems engineering (SeSE) differs from societal systems engineering in being much more concerned with material “things”, while less concerned with the intellectual welfare and happiness of person, family and society.

Societal systems engineering (SSE) is concerned with people in their social, cultural and personal contexts. SSE seeks to promote harmony, synergy, creativity and happiness, to enhance human and social capital, and to alleviate the human condition.

Human motivation

A respected view of humans and their motivations is expressed in Abraham Maslow’s Hierarchy of Needs, Table 1. (Maslow, 1943).

Table 1: Maslow's Hierarchy of Needs

5	Self-actualization	Morality, Creativity, Spontaneity, Problem-solving, Lack of prejudice, Acceptance of facts.
4	Esteem	Self-esteem, Confidence, Achievement, Respect of others, Respect by others.
3	Love/belonging	Friendship, Family, Sexual intimacy.
2	Safety	Security of: body, employment, resources, morality, the family, health, property.

1	Physiological	Breathing, Food, Water, Sex, Sleep, Homeostasis, Excretion.

Maslow used the terms Physiological, Safety, Belongingness, Love, Esteem and Self-actualization to describe the pattern that human motivations generally go through. Level 1 identifies the basic physiological needs of life. Maslow identified Levels 2, 3 and 4 as “deficiency needs”: if these needs are not met then the body gives no physical response, but the individual feels anxious and tense. These needs must be satisfied before the individual moves on to “being needs” at the top, Level 5.

Noticeable within Maslow’s Hierarchy are the predominance of personal and interpersonal needs. Between them, social engineering (SE) and socioeconomic systems engineering (SeSE) leave levels 3, 4 and 5 largely untouched; creating contexts and environments, in which the needs expressed in these upper levels may flourish, is one goal of societal systems engineering (SSE.) .

Understanding the human condition

The nature of the human condition is controversial. It reflects that humans, unlike most other animals, are self-aware and introspective. The human animal is concerned about an uncertain future, worried about what becomes of us and our offspring when we die, looks for purpose and “meaning of life”, while recognizing that we are, each of us, ultimately alone inside our minds. Part of the human condition is to crave freedom, yet be beset by worries and concerns. Equally, part of the human condition is to be curious and creative, to seek and solve problems, to anticipate and plan ahead…

We humans seek happiness, too, but may not be sure what happiness is…to some it is the acquisition of material wealth. A more insightful view proposes that "happiness is absorption" (Lawrence, 1997): if we are totally absorbed in activity, in pursuit, in creation, in solving problems, in living for the moment, even childlike, then we are fulfilled and have no need or time for introspection, to worry about mortality and the hereafter…

We evolved as a species to live in small groups. Isolated tribes still live in remote parts of the world in much the same way as 30,000 years ago: it is remarkable how such tribes thrive, giving every appearance of being dignified, content-yet-curious, happy, totally absorbed with everyday living, hunting, fishing, gathering, house- and boat-building, and raising robust families, without any need for the outside world.[11] Do they, perhaps, exhibit the quintessence of the human condition that we are too sophisticated to appreciate?

---

[11] E.g., see BBC TV series Amazon, Episode 3, with Bruce Parry and the Marubo tribe.

A world of 7 billion people cannot go back to living in the Stone Age; although, some religious fundamentalist would like us to return to much simpler times. The human condition has significantly improved, however, in measurable aspects such as health, longevity and education: this at the expense of non-measurable aspects such as happiness, contentment, freedom of thought, freedom from fear, sense of purpose, opportunity to live for the present without unnecessary concern for the future… see table 1.

Societal systems engineering in the UK

Realization that big cities can be problematic is not new: it was evident in victorian times, when everyday life in the cities was rougher that today. To this end, governments before and after WWII have actively practised SSE by creating much more appealing, less crowded, less threatening environments in various forms.

Ebenezer Howard inspired the urban planning of garden cities, figure 6, (Howard, 1902), such as Letchworth and Welwyn, and his ideas spread worldwide:

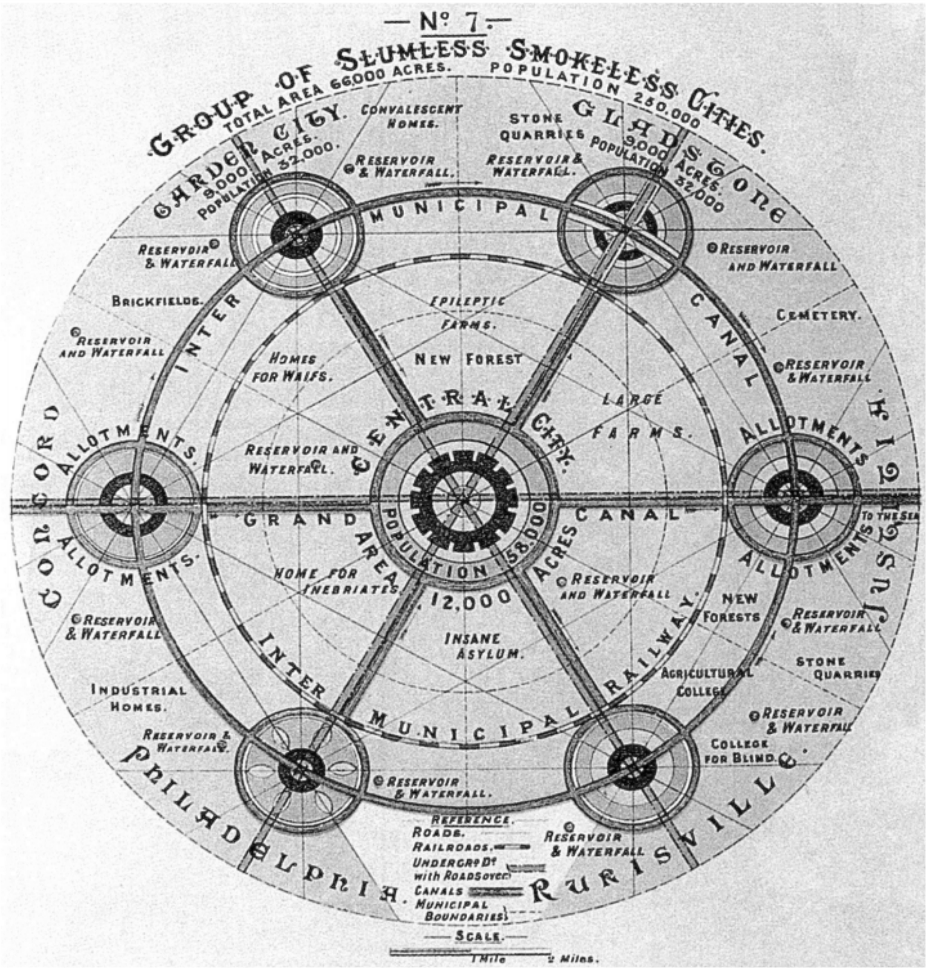


Figure 6: Garden cities of tomorrow, ebeneezer howard (1850-1928).

- Howard believed that all people agreed the overcrowding and deterioration of cities was one of the troubling issues of their time.
- Garden cities were to be planned, self-contained communities surrounded by "greenbelts" (parks), containing proportionate areas of residences, industry and agriculture, i.e. a complex, integrated, self-sufficient system in a supportive, pastoral environment.
- His plan was for each garden city to have a maximum population, largely of blue-collar workers, who would have no need to travel outside of the garden city for work;
- If the population exceeded the limit, a new garden city would be developed nearby…
- So self-contained garden cities would spread across the nation as population increased, mutually separated and interspersed by green belts.

There are many other aspects to SSE than the creation of congenial, self-sufficient living conditions, insightful although these may be. Garden cities go only some way toward recreating the contexts and environments — proposed to advance the human condition — in which we humans evolved.

However, Howard's approach of creating environments in which cultures could flourish in self-sufficient harmony and synergy (instead of controlling populations, concentrating them in cities and deciding "what was best for them") does suggest an alternative way of accommodating growing, yet potentially happy, creative, free, productive populations.

Societal systems engineering in the new kingdom of ancient egypt

The new kingdom of ancient Egypt saw the Pharaoh as the focus of societal stability: all power was, seemingly, vested in him. As figure 7 shows, he had three interlocking roles:

1. Pharaoh was a living god, Horus-Osiris, second only in the pantheon to Amun-Ra, the Sun god: see black loop in figure. As Horus-Osiris, Pharaoh was believed to oversee the judgment of the dead…He promoted the pursuit of eternal life, entry into which required that the citizen behave in an ethical manner during this life, else… no afterlife.
2. Pharaoh was the "Uniter of the Two Lands", a traditional title showing his supremacy over both Lower and Upper Egypt; he owned all of the land, which he ruled via Viziers and nomarchs, (appointed provincial governors, or nobles, who acted with the power of the pharaoh); see blue loop. Pharaoh was also ultimately responsible for Ma'at, the ancient Egyptian concept of truth, (cosmic) balance, order, law, morality, and justice, to

administer which he employed a middle class bureaucracy, a professional civil service throughout the land.

3. Thirdly, Pharaoh was the military leader, ruler of the army, conquering all foreigners and securing all borders: see red loop. Pharaoh would publicize his military prowess on the walls of temples for all to see.

As figure 7 also shows, there was an incipient flaw in the system: the widespread pursuit of eternal life placed the growing priesthood in an increasingly powerful position to accumulate wealth and possessions. Eventually they would become wealthier than the Pharaoh — but for the time being, the societal system held together remarkably, in the firm-but-benevolent grip of the god-Pharaoh. This was apparently successful societal systems engineering within a rigid class structure and without a vestige of democracy… suggesting that neither class mobility nor democracy may be quite the fundamental issues that today's politicians and agitators avow…

Pharaoh was the focus for all matters spiritual and temporal throughout the Two Lands, while he was governed, in his turn, through his responsibility for Ma'at. Pharaoh had a psychological "whip hand": anyone who misbehaved in life would come before him in death, from which there was no escape. Good behaviour in life meant giving to the poor, protecting widows and children, etc. Having performed these social essentials in life was necessary, but not sufficient: additionally, dead souls had their hearts weighed against the ostrich feather of Ma'at (truth); if their hearts were lighter than the feather, they would gain entry to the afterlife… and, Pharaoh as Horus-Osiris was final arbiter; or so they believed.

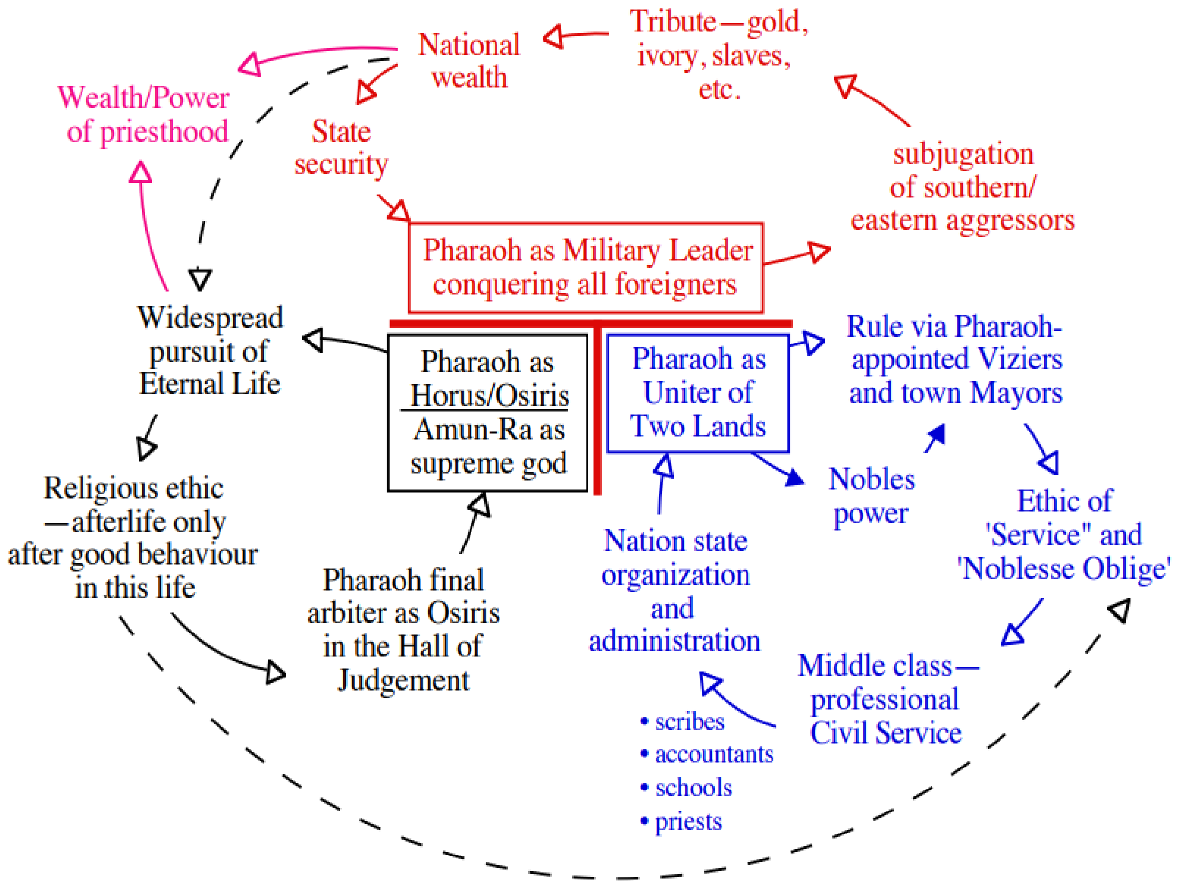

National wealth
Tribute—gold, ivory, slaves, etc.
Wealth/Power of priesthood
State security
subjugation of southern/ eastern aggressors
Pharaoh as Military Leader conquering all foreigners
Widespread pursuit of Eternal Life
Pharaoh as Horus/Osiris Amun-Ra as supreme god
Pharaoh as Uniter of Two Lands
Rule via Pharaoh-appointed Viziers and town Mayors
Nobles power
Ethic of 'Service" and 'Noblesse Oblige'
Religious ethic —afterlife only after good behaviour in this life
Pharaoh final arbiter as Osiris in the Hall of Judgement
Nation state organization and administration
Middle class—professional Civil Service
• scribes
• accountants
• schools
• priests

Figure 7: Societal stability and the pharaoh in the New Kingdom.
Causal Loop Model. Open arrows support: solid-head arrows resist…

An indication of the nature, character and sophistication of the people was the so-called Negative Confession, much rehearsed in life, which their spirits were required to make to Horus-Osiris upon entering the Hall of Judgement. See Table 2, which presents Spell 125 from the Book of the Dead, one version of the negative confession, from which it may be reasonably deduced that both social and spiritual balance were important in the functioning and well being of that society, over three and a half millennia ago.

Table 2: The ancient Egyptians' negative confession-Egyptian book of the dead,

…extracted from spell 125 (Faulkner, 1985).

1. I have done no falsehood	2. I have not robbed	3. I have not been rapacious.	4. I have not stolen.	5. I have not killed men
6. I have not destroyed food supplies	7. I have done no crookedness	8. I have not stolen the god’s offerings	9. I have not told lies	10. I have not taken food.

11. I have not been sullen.	12. I have not transgressed.	13. I have not killed a sacred bull.	14. I have not committed perjury.	15. I have not stolen bread.
16. I have not eavesdropped.	17. I have not babbled.	18. I have not disputed except as concerned my own nproperty.	19. I have not committed homosexuality.	20. I have not misbehaved.
21. I have not made terror.	22. I have not transgressed.	23. I have not been hot-tempered.	24. I have not been deaf to words of truth.	25. I have not made disturbance.
26. I have not hoodwinked.	27. I have neither misconducted myself nor copulated with a boy.	28. I have not been neglectful.	29. I have not been quarrelsome.	30. I have not been unduly active.
31. I have not been impatient.	32. I have not transgressed my nature, I have not washed out (the picture of) a god.	33. I have not been voluble in speech.	34. I have done no wrong, I have seen no evil.	35. I have not made conjuration against the king.
36. I have not waded in water.	37. I have not been loud voiced.	38. I have not reviled God.	39. I have not done…	40. I have not made distinctions for myself.
41. I am not wealthy except with my own property.	41. I am not wealthy except with my own property.			

The negative confession of the polytheistic ancient egyptians stands in counterpoint to the more positive, biblical ten commandments (Decalogue) of the monotheistic Jews and some Christians, e.g. “Thou shalt not kill”, “Thou shalt not steal.” Nevertheless, both sets of admonitions address concern for social and spiritual well-being of individuals, and may have been penned at much the same time; however, they also reveal societal and cultural differences… For example, there is nothing in the Egyptian negative confession about: adultery, honouring parents, coveting a neighbour’s wife, etc., suggesting that such infractions of Hebrew commandments would not have been heinous crimes to the Egyptians, either because they did not happen or they did not care. On the other hand, there is plenty about intemperance, interpersonal relationships, unfair-trading, purloining food, loud, excessive and antisocial behaviour, homosexuality and pederasty, religious observance, etc..., suggesting the existence of widespread contemporary Egyptian social ethics and morality…

It is reasonable to assume that ancient Egyptian society was significantly less sophisticated than today's: politics and economics had not been invented, neither had theology, since there was no separation into sacred and secular; all of life was seen as occurring in the presence of the gods. There was little difference in the standing in law between men and women. Boys learned their trade from their fathers, women from their mothers. Women could serve in the temples of Hathor and Isis, female deities, while men might serve in the male counterparts, Amun-Ra, Sobek, etc. Health was a problem, with high maternal and infant mortality rates; while broken bones could be reset, problems with internal organs were not well understood, and the only antibiotic was honey, which was put on wounds to help them heal. (Aldred, 1961: Szpakowska, 2009).

Overall, during this second golden age of ancient Egypt, the impression emerges of a busy, occupied, largely unsophisticated population made up of many loosely-connected settlements and societies living up and down the Nile, getting on with the daily business of growing crops, raising cattle, praying to the gods for good Inundations, marrying, raising families, and so on… there seemed to be little for the average person to worry about outside of his and her absorbing everyday lives.

At the same time, there was a continuing outburst of creativity in architecture, literature, art, jewellery, and furniture, much of which still remains for us to admire. Looking back at table 1. Maslow's Hierarchy of Needs above, it seems that Egyptian society in the new kingdom was motivated to be self-actualising at the highest level. We may tentatively deduce that their lives, which — apart from the upper class — revolved largely around trading, agriculture, husbandry, fishing, making clothes, and raising families, would have been a satisfying and absorbing one; for those concerned with fine arts, perhaps even more so. And, they had an abiding belief in life after death; that they would go, with their families, to an afterlife which would be similar to their everyday lives, but even more comfortable, suggesting that those everyday lives were more than acceptable.

Summary. Comparing life in present day UK cities with New Kingdom Egypt — in terms of standard of living and, particularly, the human condition — suggests that the ancient Egyptians may, on average, have been less sophisticated and rather happier. Of course, they had no telephones, TV, wireless, etc..., and medical care was limited, but these modern manifestations count little toward human happiness, family, contentment, assurance of the hereafter, creativity, etc.; they appear — at a considerable distance, admittedly — to be have been content. This despite (or because of?) relative unsophistication, lack of science and engineering, and a vibrant society within a firm class structure in which there was a place for everyone, no social mobility and no democracy…

Summary and conclusions

A distinction has been drawn between social engineering (not a form of systems engineering), socioeconomic systems engineering (SeSE), and societal systems engineering (SSE). Historically, societies have been the subject of social engineering by despots, demagogues and governments, often to their own ends. UK politicians practice social engineering under the guise of parliamentary democracy, where competing political parties take it in turn to engineer society according to their contrasting, left VS right, and upper, middle and lower class ideologies. The many laws, social movements and changes occurring since WWII, seemingly innocuous or even worthy at the time, have combined to progressively degrade the human condition. Significant improvements in measurable aspects of the human condition such as individual health and longevity have been made, but are threatened by increasing social disorder, widespread fear, misbehaviour, obesity, alcohol and drug abuse, related medical conditions, reduced freedom of speech and privacy, etc…

Socioeconomic systems engineering, also driven largely by government, emphasises the materialistic aspects of “social sufficiency”, establishing and maintaining a complex infrastructure of actions and interchanges between raw materials industries, manufacturing industries, service industries, farming industries, and society at large. The goal of socioeconomic systems engineering is primarily the provision of resources, so maintaining and improving material aspects of the quality of life; it can also enhance human capital through — particularly — higher education. UK education generally, however, is observed [e.g. by the organization for economic cooperation and development (OECD) (Loveys, 2010), (Young, 2012)] to have seriously degraded in recent years with respect to other nations. Globalization is seen as somewhat experimental, with inherent risks and necessary precautions, which are not evidently being taken…

Societal systems engineering (SSE) is concerned with alleviating and enhancing the human condition, which has been progressively degraded since WWII by increasing urbanization and mutual isolation between city and country, side-lining of Christianity, and dystopian political correctness, with misguided application of health & safety legislation provoking a nationwide risk-averse/compensation culture. Together, these have stifled free speech, restricted behaviour, inhibited learning and creativity, imposed a nationwide atmosphere of fear and suppression, and restricted freedom of thought, speech and deed. Political correctness as an oppressive, totalitarian controller and regulator of UK social speech and behaviour, may be adversely compared with the ancient Egyptian “negative confession”, which identified personal practices and behaviours that would potentially tip the balance against a believer’s prospects of attaining afterlife, so encouraging “acceptable” individual social behaviour in life…

An indicator of the diminishing human condition is the perpetual state of fear for their children in which people presently live. Whereas 60 years ago children roamed free, now they are rarely allowed out of the house alone. They used to go to school on their own: now they are taken and collected. They may come from homes where their parents are not married, or from single parent families, or from homes where mother has taken a second or third partner. They are not brought up in the way that their forebears were, within a nuclear and wider family: instead they go to nursery school, and are unavoidably “educated” by their peers; some parents seem no longer capable—or concerned. The Welfare State, well meaning though it may be, is no substitute for bringing up children within an intellectually stimulating, nurturing and physically safe family, with both biological parents.

The social structure that, for the last ninety thousand years has been formed around the nuclear and extended family, integrated with the natural world, and synchronized with the seasons, is becoming progressively atomized, accelerated and concentrated into ever-larger cities. Humans are not evolved to live in cities, insulated and isolated from the natural world of which they are properly an integral part. Obesity, self-mutilation, masturbation, attacking own offspring, stomach ulcers, fetishism, homosexual pair-bonds, murder, etc. occur with city dwellers, as they do with captive animals in a zoo. Such behaviours are evidence of a severely prejudiced human condition…

[Significantly, city-living humans tend to take their holidays in the countryside, at the seaside, on the beach, etc., subconsciously, perhaps, responding to the need for time in their natural human environment in which to relax, slow down and alleviate the human condition, if only temporarily. Others seek peace and relaxation in enclosed gardens with grass, flowers, fruit, foliage and running water, to isolate themselves briefly from other humans, and to recreate their natural environment in miniature.]

City life can be attractive, exciting and challenging, especially to the young, who may consider themselves urbane, superior and sophisticated compared with their ‘country cousins:’ sophistication may be a veneer of self-delusion. Cities, it appears, may be the problem, rather than the solution, in alleviating the human condition. Blueprints for potentially better ways of living, such as Ebenezer Howard’s insightful “Garden cities of tomorrow”, which addressed both socio-economics and quality of life/human condition issues, met with only partial uptake and have effectively stalled. Such approaches were “of their time”, but their aims were laudable: we lack contemporary counterparts, which can accommodate a global population of over seven billion and rising…

In place of social engineering

Is there anything beyond these three:

1. Social engineering (SE), somewhat blindly driven by competing political ideologies;
2. Socioeconomic systems engineering (SeSE), with its materialistic emphasis; and,
3. Societal systems engineering (SSE) with its emphasis on synergy, quality of life and alleviating the human condition?

Of these three, the first, social engineering, predominates. Politicians do attempt to address measurable aspects of the human condition, with promotion of health services, education and some "culture", but their efforts are marred by ideological differences between parties, and their focus on the city at the expense of the country. In times of trouble, politicians are more aware of socioeconomic issues, too, and concern themselves with the ability of the poor to "pay their way".

Which begs the question: what is the purpose, aim and goal of government? We might, in an abstract, idealistic sense, suppose it to be: "the provision and maintenance of a secure, nurturing and supportive national environment in which individuals, families and businesses may thrive and prosper in harmony with the natural world".

If that were truly the aim, then the third listed item above would be seen as more important. Indeed, the second and third items, socioeconomic systems engineering and societal systems engineering taken together could replace ideological social engineering altogether as the stuff of government, both central and local. For this to take effect would require politicians to ditch their ideologies and choose instead to take a systems approach to societies and socioeconomics. As things stand, the socio- in socioeconomics is poor relation to the economic aspects. Perhaps we have need of a new, combined discipline: Societal & economic systems engineering…where the emphasis is on societal systems engineering aimed at alleviating the human condition, together with human and social capital, within a self-sustaining economic framework. Using such a discipline, there may be recipes for moving towards a different way of living for many people, such that the human condition may be restored and enhanced. Although, implementing such recipes would almost inevitably involve social engineering…

References:

- Ajzen, I, Fishbein, M.(1980) Understanding Attitudes and Predicting Social Behaviour, Prentice Hall, NJ.
- Aldred, C, (1961) The Egyptians, Thames and Hudson, London.
- Bernstein, R. (1990). "IDEAS & TRENDS; The Rising Hegemony of the Politically Correct — The New York Times". Retrieved May 22, 2010.
- Clayton, P.A. (1994) Chronicle of the Pharaohs, Thames & Hudson, London.
- Faulkner, R.O. tr. (1985) The Ancient Egyptian Book of the Dead, University of Texas Press, Austin, TX.
- Golding, W. (1954) Lord of the Flies, Faber and Faber, London.
- Hargrave, A. (2005) The Psychology of Shopping 140305, www.bized.co.uk.
- Hawkes, C., (2004) Human Longevity — the Grandmother Effect, Nature 428.11.
- Hill, J.O. and Peters J.N. (1998) Environmental Contributions to the Obesity Epidemic, Science, 280: 5368 pp. 1371-1374.
- Hitchens, P, (1999) The Abolition of Britain, Quartet Books, UK.
- Hitchins, D.K.(2003) Advanced Systems Thinking, Engineering and Management, Artechhouse, Norwood MA.
- Hitchins, D.K. (2007) Systems Engineering: A 21st Century Systems Methodology, Wiley and Sons, Chichester, England.
- Hitchins D.K. (2010) The Pyramid Builders' Handbook, Lulu Publishing.
- Howard, E. (1902) Garden Cities of To-morrow, 2nd edn, S. Sonnenschein & Co. Ltd., London.
- Jung, C.G., (1976) The Portable Jung, Penguin Books USA Inc.
- Lawrence, T.E. (1997) Seven Pillars of Wisdom, Wordsworth Editions Ltd.,Herts., UK.
- Loveys, K (2010) OECD condemns British education, http://www.dailymail.co.uk/news/article-1336410/OECD-condemns-British-educationinferior-Estonias.html.
- Maslow, A.H. (1943) A Theory of Human Motivation, Psychological Review, 50, pp. 370-396.

- Morris, D. (1994) The Human Zoo, Vintage, London, UK.
- Morris, D., (2005) The Naked Ape: A Zoologist's Study of the Human Animal, Vintage London, UK.
- Moyer, M.W. (2012) The Motherhood Gap, Scientific American, 306.6.
- Orwell, G. (1949) Nineteen Eighty-Four, Socker and Warburg, London.
- Parcel, T., Campbell L.A., Wenxuan Zhon, (2012) Children's Behavior Problems in the United States and Great Britain, Journal of Health and Social Behavior.
- Rice, Michael (1990) Egypt's Making, Guild Publishing, London.
- Strauss, M. (2012) Looking Back on Limits to Growth, Smithsonian Magazine, April 2012.
- Szpakowska, K, (2008) Daily Life in Ancient Egypt, Blackwell Publishing, Malden, MA.
- Young, T. (2012) Dumbing down of state education has made Britain more unequal than 25 years ago, http://www.telegraph.co.uk/education/9082053/Dumbing-down-of-stateeducation-has-made-Britain-more-unequal-than-25-years-ago.html, accessed 25 May 2012.

Natural systems engineering

Abstract

Natural systems have evolved on Earth over some 542MY, through trial and error, by natural selection, with such exemplary results as the human body, one of the most complex organisms on the planet.

The human body exhibits different "levels of organization": organization appears at each level. "Nature's design" evidences a higher degree of coupling and mutual interdependence between structures at the same level of organization, for example between organ systems, than is the usual case for supposedly equivalent manmade systems. The human brain also exhibits levels of organization, but these do not find correspondence in manmade processing systems, while the operation of the brain's remarkable memory is still uncertain, with many clues, but conflicting ideas amongst neuroscientists.

Homeostasis in organisms can be singularly complex, with stabilizing "mechanisms" that differ markedly from those employed by cyberneticists and engineers: could the latter learn to advantage from successful, natural systems?

Nature has also created extensive insect social systems, so-called "super organisms". Honeybees have existed for more than 100MY, ants over 120MY and termites over 150MY, suggesting they have a variety of successful survival strategies. Modern humans have been on the planet barely 2MY so far… and already threaten their own survival together with that of many other species.

Overall, nature has an enviable "track record" of evolving efficient, adaptable, effective, survivable organisms and super-organisms that exist in more-or-less mutual harmony with other organisms and super-organisms.

Biomimetics, similar to biologically inspired design, is the study of the structure and function of biological systems as models for the design and engineering of materials and machines. Together with ecology, biomimetics (Bar-Cohen, 2011) and biomimicry (Benyus, 1997), may also offer sophisticated models, processes and procedures for:

- Systems thinking.
- Systems conception.
- Systems design.
- Systems architectures.
- Systems lifecycles.

- System survival strategies.

... and many more as yet largely untapped. Can such models be employed to advantage for manmade systems, human systems, societal systems, business and industry systems, systems engineering, even economic systems? Are they applicable, can they be trusted, if they are different, *why* are they different, is their efficacy amenable to proof? These are questions to ponder, while at the same time admiring the legacy and insight the models may provide.

Levels of organization

Biologists and anatomists identify so-called "levels of organization" within living things. Levels of organization describe the way in which organisms are synthesized, starting with the cell, the smallest living entity. Cells are complex miniature factories creating proteins; they have emergent properties.

Cells of differing kinds may be organized into tissues, the next level of organization. Tissues are formed from the emergent properties of their constituent cells. Tissues are more complex than cells; they "contain" the complexity of many interacting cells. Tissues may be: connective, muscle, nervous and epithelial.

Tissues of different kinds may come together to form organs. An organ is a collection of tissues joined in a structural unit to serve a common function. In the human body, the heart, liver, kidneys, etc..., are organs, formed from the emergent properties of their constituent tissues. A kidney comprises nephrons, the principal functioning units of the kidney, filtering blood and producing urine; nephrons comprise complementary tissues made from many different cells, all set in a collagen framework or scaffold.

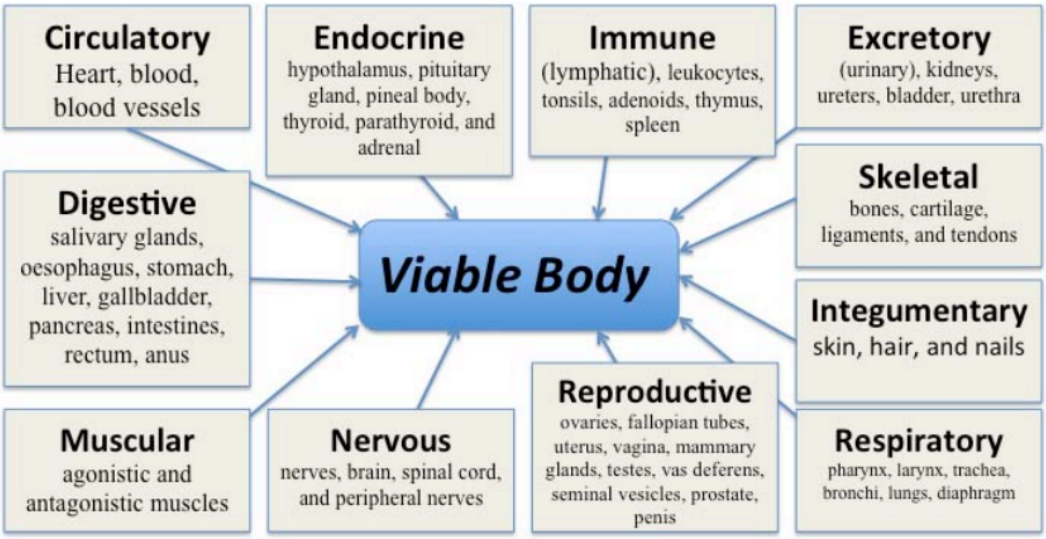

Circulatory
Heart, blood, blood vessels
Endocrine
hypothalamus, pituitary gland, pineal body, thyroid, parathyroid, and adrenal
Immune
(lymphatic), leukocytes, tonsils, adenoids, thymus, spleen
Excretory
(urinary), kidneys, ureters, bladder, urethra
Digestive
salivary glands, oesophagus, stomach, liver, gallbladder, pancreas, intestines, rectum, anus
Viable Body
Skeletal
bones, cartilage, ligaments, and tendons
Integumentary
skin, hair, and nails
Muscular
agonistic and antagonistic muscles
Nervous
nerves, brain, spinal cord, and peripheral nerves
Reproductive
ovaries, fallopian tubes, uterus, vagina, mammary glands, testes, vas deferens, seminal vesicles, prostate, penis
Respiratory
pharynx, larynx, trachea, bronchi, lungs, diaphragm

Figure 1: Organ systems in a viable body.

The body is comprised of organs that work together as organ systems; there are some ten to twelve major organ systems in the body, depending upon how they are counted. See figure 1, which shows the viable body’s organ systems together with their constituent organs.

Learning from natural levels of organization

There are discernable levels of organization within the human body.

5. Organism — 4. Organ system — 3. Organ — 2. Tissue — 1. Cell

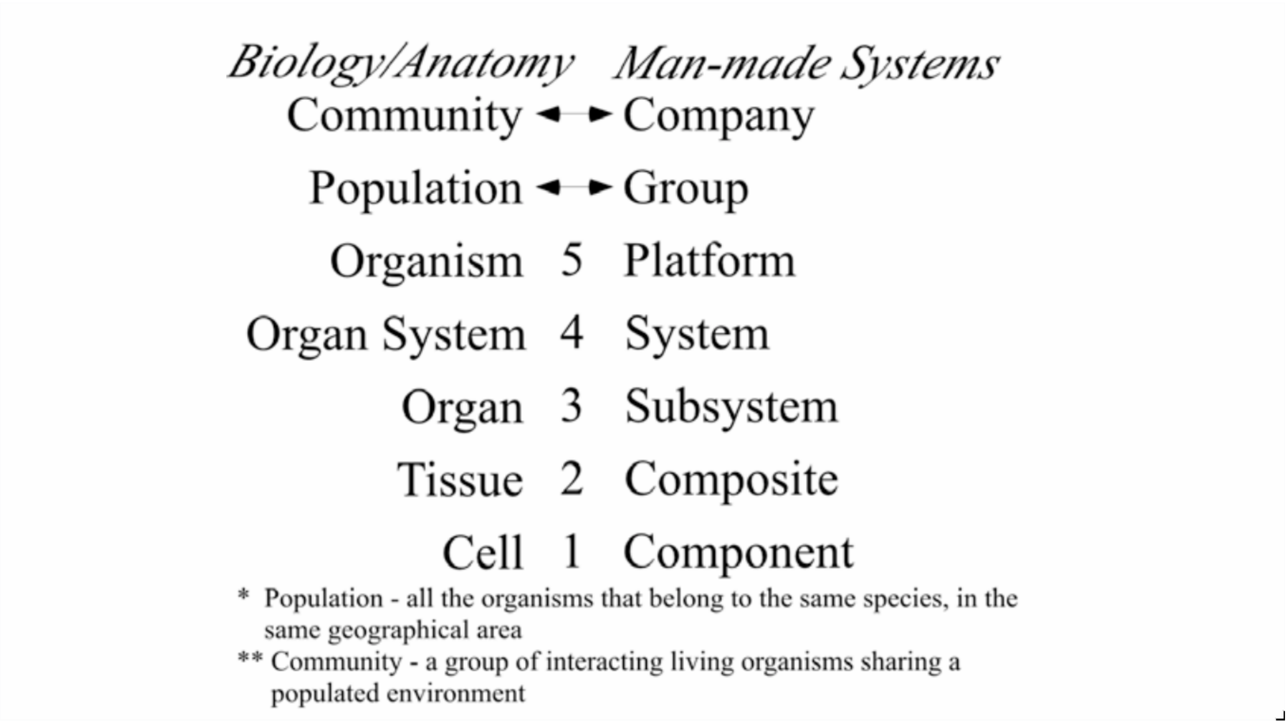
Each level is formed from the emergent properties of assemblages and combinations of the level below. At each level there may be many of same-or similar-kind, mutually interacting entities.

Biologists identify some 210 different human cell types. Different cell types organize into different tissues. Different tissue types organize into organs. Different organs organize into organ systems. And, different organ systems organize into the human organism. There is, however, a formative sequence within the embryo.

A human embryo grows around an axis, which will become the spine and spinal cord. The heart, brain, spinal cord and gastrointestinal tract form initially, followed by limb buds and internal organs. Each of these follows (depends upon?) the prior existence in the embryo of heart, brain and nerves; they do not appear independently and then “join up”, as it were… so there is no reduction, only synthesis and development, with nerves, blood vessels, etc., developing within, and at much the same time as, the tissues and organs. Remembering, of course, that the embryo is developing according to a well established “master plan” in the DNA.

Extending the “levels of organization” paradigm

Figure 2 shows the cell-to-organism hierarchy diagrammatically from bottom to top: cell, tissue, organ, organ system, organism and then extended beyond to population and society (and, not shown, continuing above to ecosystem and biome, both of which include non-living “things”.) At right is a supposed correspondence with man-made systems, such that organ system corresponds with system at level 4, organism with platform, at level 5, etc…



Biology/Anatomy		*Man-made Systems*
Community	◄–►	Company
Population	◄–►	Group
Organism	5	Platform
Organ System	4	System
Organ	3	Subsystem
Tissue	2	Composite
Cell	1	Component

* Population - all the organisms that belong to the same species, in the same geographical area

** Community - a group of interacting living organisms sharing a populated environment

Figure 2: Levels of organization — Organic and manmade systems

Correspondence at levels 1 and 2 is more questionable. While a cell is a living thing, a man-made component, an artefact, is not; neither is a composite of such inert components. However, components may be energised and may be active; for instance, a field-programmable gate array (FPGA) may be programmed to perform a variety of functions. While energized, such electronic devices/components may not unreasonably correspond with cells. Similarly, tissues may reasonably correspond with energized assemblages of such active devices, referred to as composites. Neither component nor composite, however, seems to quite merit the epithet of “system”, since they are not “organized coherent wholes”.

Levels 3 and 4 are more promising: an organ system corresponds sensibly with a system consisting of interacting subsystems that perform functions, and have “organized whole” characteristics. Similarly, an organism corresponds sensibly with platform, in that a platform, like an organism, carries its organ systems around with it “internally”, i.e., sensors, processors, etc…

Population is less clear. All workers in a hive of honeybees, for example, are sisters. Such cannot be said of humans forming a group, and the difference may be important: hive behaviour is highly motivated towards the survival of the queen and the next generation, and this behaviour may be dependent upon their being closely related genetically, and therefore willing to supress their own need to reproduce as they are, in effect, furthering their own genes in caring for the offspring of the queen.

The implication at community level is of different species interacting in the same populated environment, which might be less obvious for humans in interacting groups, since all humans are of the same species. Perhaps we may consider human groups with different cultures, disciplines, faiths or beliefs as corresponding conceptually with different species — at least in some degree.

One curious note presents itself; that a hierarchy of man-made systems bears such apparent similarity with that found in human biology/anatomy. Three explanations come to mind:

1. That the notion of hierarchy is simply a naturally occurring property of complex systems in that emergent properties and behaviour happen at various scales in complex systems.
2. That the hierarchy for man-made systems is innate to humans as designers and creators, and may have emerged from their subconscious.
3. That the hierarchy for man-made systems has been consciously based upon the natural hierarchy found by biologists and anatomists.

Then again, many of those engaged in early work on systems were biologists, one of whom was instrumental in developing General Systems Theory (Bertalanffy, 1968).

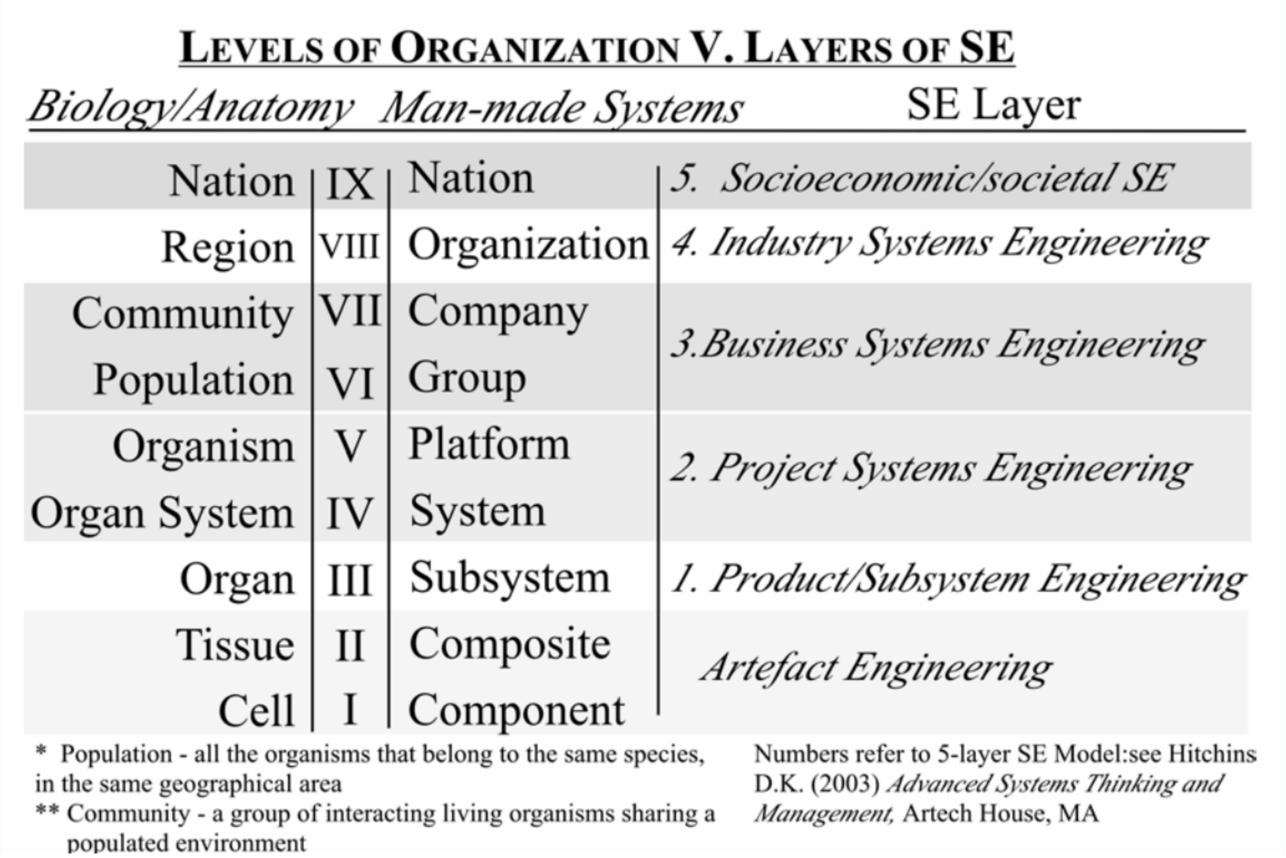
Levels of organization and layers of systems engineering

Levels of organization indicate successive levels of complexity. Systems engineering seeks to manage complexity in the conception, design and synthesis of complex manmade systems. There is an evident correspondence between levels of organization, and various “flavours” of systems engineering.

Figure 3 presents correspondence between three parallel hierarchies: levels of organization; manmade systems; and, layers of systems engineering. An “anchor” point of correlation/correspondence is between organ system: level IV: system; and, layer 2, project systems engineering.

This sits comfortably above organ: Level III: Subsystem; and, layer 1 product/subsystems engineering, where an organ is evidently a functional subsystem of an organ system, and product/subsystems engineering is evidently one level down on project systems engineering, since a project is likely to comprise a number of interacting functional products.

That leaves business systems engineering addressing company and group; industry systems engineering addressing organizations; and, socioeconomic/societal systems engineering operating at national level.



LEVELS OF ORGANIZATION V. LAYERS OF SE

Biology/Anatomy		*Man-made Systems*	SE Layer
Nation	IX	Nation	*5. Socioeconomic/societal SE*
Region	VIII	Organization	*4. Industry Systems Engineering*
Community	VII	Company	*3.Business Systems Engineering*
Population	VI	Group	
Organism	V	Platform	*2. Project Systems Engineering*
Organ System	IV	System	
Organ	III	Subsystem	*1. Product/Subsystem Engineering*
Tissue	II	Composite	*Artefact Engineering*
Cell	I	Component	

* Population - all the organisms that belong to the same species, in the same geographical area
** Community - a group of interacting living organisms sharing a populated environment

Numbers refer to 5-layer SE Model:see Hitchins D.K. (2003) *Advanced Systems Thinking and Management,* Artech House, MA

Figure 3: Levels of organization and layers of systems engineering.

The figure suggests that "ascending" layers of systems engineering address "increasing" levels of organization, therefore increasing degrees of complexity. Further, the figure suggests that systems engineering, at any layer, is essentially the integration of parts from the level below. So, industrial systems engineering is the integration of several/many interacting businesses into a coherent industry. Business systems engineering is the integration of several/many projects into a coherent business. And so on...

The figure also indicates that business/enterprise, industry and socioeconomic systems engineering are primarily concerned with increasingly complex people systems, rather than technology. As such, systems engineering will be concerned, less with technology, more with decision-making and behaviour, operations, management, organization, resourcing, training, control, contribution, coordination and cooperation, belief systems, Weltanschauungen, group psychology, social anthropology, etc…

Meanwhile, at the lower end,levels II and I, the figure suggests that there is "less systems engineering, more conventional engineering", since both components and composites are manmade artefacts, not systems in the sense of being whole, internally-organized entities performing functions.

The potential value of this structural relationship is for a cross fertilization between the three hierarchies at each and any level. It presents a different view of systems engineering as being about integrating subsystems where each is mutually interdependent on all the others…

The triune brain

The triune brain is a model of the evolution of the vertebrate forebrain and behaviour proposed by the American physician and neuroscientist, Paul D. McLean. The Triune ("three in one") brain consists of the reptilian complex, the paleo-mammalian complex, and the neo-mammalian complex (neocortex), viewed as structures sequentially added to the forebrain in the course of evolution:

1. The reptilian brain: responsible for species-typical instinctual behaviours involved in aggression, dominance, territoriality, and ritual displays.
2. The paleo-mammalian brain, otherwise the Limbic System: responsible for the motivation and emotion involved in feeding, reproductive behaviour, and parental behaviour.
3. The neo-mammalian complex, or cerebral neocortex: responsible for language, abstraction, planning, and perception.

These three are less "Levels of organization", more evolutionary overlays. The Triune Brain model has been partly overtaken by recent research, but it still offers a seductively straightforward way of regarding the human brain.

The Triune Brain does offer one potential model — that of layered processing. Instead of replacing redundant computing systems, with their accumulated wealth of software and data, perhaps these systems could be retained as a nucleus and surrounded with "shells" of advanced processing permitting faster calculation, correlation, communication and control such that computing systems might interact with humans via speech and vision, rather than keyboards and mice… and might anticipate the human need for planning and presentation…

Layers in the brain

The human brain is the most complex part of the human body, and although some may like to compare it with a computer, and/or with the software of a computer, such comparisons do not seem to offer useful models by which we might advance our manmade computing systems… so far.

The cerebral cortex is the outermost sheet of neural tissue of the cerebrum of the human brain. It is divided into left and right hemispheres, and plays a key role in memory, attention, perceptual awareness, thought, language and consciousness. It consists of up to six horizontal layers, each with a different composition in terms of neurons and connectivity.

Levels of organization within the brain

The brain is an exceedingly complex organ that is defying attempts to analyse and — particularly — reduce its performance and behaviour. However, there have been attempts to show levels of organization within the brain, as part of the human brain project (Markram, 2012) as follows:

- Whole Organ, comprising some 89 billion neurons and 100 trillion interconnections (making over 1000 connections per neuron on average).
- Regions, mutually interacting major neural substructures: amygdala (emotions), hippocampus (memory), frontal lobes (executive control).
- Circuits, neural interconnections among neighbouring cells and between different brain areas.
- Cellular, neurons, non-neuronal glial cells, dendrites and axons.
- Molecular, parts of a neuron and its transmission of electrical and chemical signals.

On the other hand, there appear to be functional “subsystems” within the brain, concerned with speech, vision (q.v.), motor control, etc…

The human brain project is undertaking an ambitious task, employing “synthesis biology”; this is essentially simulating the human brain within a computer. As a test case, the project team built a unifying structure called a cortical column: this is described as analogous to putting a miniature apple corer through the cortex and pulling out a cylinder of tissue about one half millimetre in diameter and 1.5 millimetre in length; this would constitute a column.

The column penetrates the six vertical layers of the neocortex; the neural connections between it and the rest of the brain are organized differently in each layer. A few hundred neuron types reside in the column.

The team simulated the behaviour of a column from a new born rat, allowing the virtual neurons to connect up as real neurons would, eventually providing them with a static model of a column, as in a comatose brain. They then “jolted” the column with a simulated electrical impulse: the neurons began to interact and intercommunicate. “Spikes”, or action potentials, spread through the column as it began to work as an integrated circuit; this was spontaneous, not programmed behaviour. And the column stayed active after the stimulation stopped, briefly developing its own internal dynamics…

Observation. Here, then, is a fascinating, new way of looking at the way the human brain might work, and — although not its primary, medical purpose — it may afford potential for novel design of complex computing and information systems of the future.

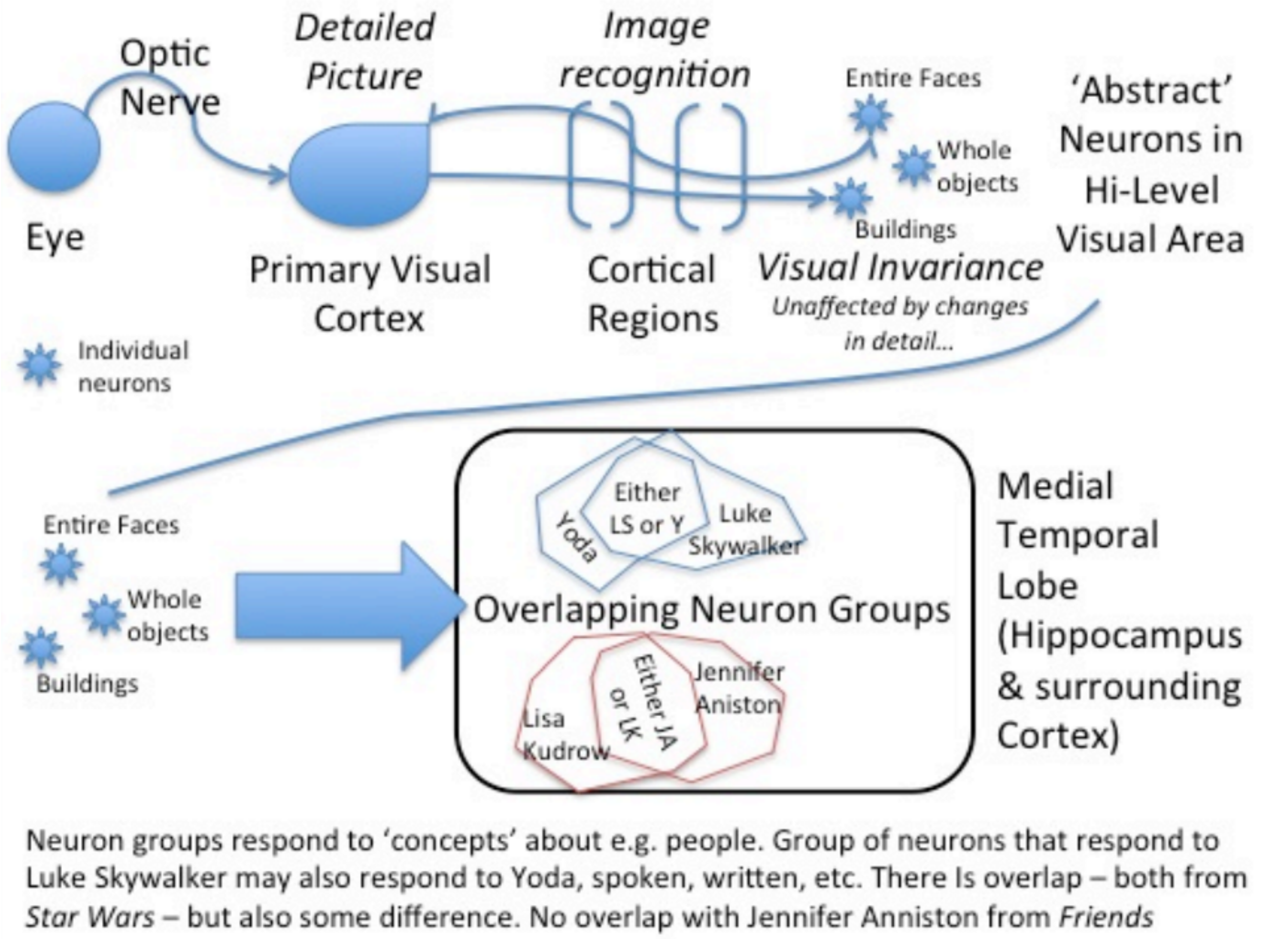
Brain cells for concepts

Neuroscientists dispute how the brain stores memories — which it does remarkably well. Some view memories as somehow spread across the brain and interspersed with each other: others suspect that memories are stored in individual neurons, or groups of neurons. Research, particularly into the brains of those with debilitating epilepsy, is showing interesting results. (Quiroga, Fried and Koch, 2013)

Researchers have been able to insert fine probes into the brain, particularly into the hippocampus, and have discovered individual neurons firing when the subject is presented with a picture of a well-know film or TV star, or has seen their name written. An individual neuron fired for Halle Berry, again to her name written on a screen, and again to her name spoken by a synthesized voice. The same phenomenon occurred for Oprah Winfrey, and for Luke Skywalker; each appeared to have his or her own “neuron”. The research team could not assert this, however, because they were able to sense only a few neurons at a time. Others could have been firing but undetected.

However, further research showed that individual neurons might fire for more than one such star. The neuron that fired for Jennifer Anniston also fired for Lisa Kudrow, her co-star on Friends. Again, it was sufficient to show any picture of either star, or the written name, or the name spoken with a synthesized voice. Perhaps the neuron was firing for blondes, or for the TV program Friends? The neuron that fired for Luke Skywalker also fired for Yoda: was there a Jedi neuron? Moreover, the neuron for e.g. Jennifer Anniston fired when shown only part of her, when wearing different clothing, etc. Such neurons, then, appeared to be firing in response to the “concept” of Jennifer Anniston, or Yoda, or… how could this be?

The organization and structure of visual information in the brain is outlined in figure 4. Top left is shown the eyeball, with the optic nerve leading to the primary visual cortex at the back of the head. Here a detailed picture is formed, such that, for every detail in the observed image, there is some correspondence in the primary visual cortex. One neuron firing does not indicate whether it is part of a tree, a wall, or a person, however, and the observer is interested in whether they are looking at an object, and if so, what object…



Neuron groups respond to 'concepts' about e.g. people. Group of neurons that respond to Luke Skywalker may also respond to Yoda, spoken, written, etc. There Is overlap – both from *Star Wars* – but also some difference. No overlap with Jennifer Anniston from *Friends*

Figure 4: Concept memory.

Next the visual information goes through a series of cortical regions towards the front of the brain. Individual neurons in these higher visual areas respond to entire faces, or whole objects, and not to local detail. So, minor changes in the visual scene will not affect these neurons. This is "visual invariance".

Neurons in the higher visual areas send their information to the medial temporal lobe – the hippocampus and surrounding cortex – which is involved in memory functions and where the so-called Jennifer Aniston neurons were found. The response of neurons in the hippocampus is much more specific than in the higher visual cortex. Each neuron responds, not so much to an individual, as to a concept of some individual.

As the figure suggests, there may be a "patch" of neurons, a relatively sparse grouping, which respond to, say, Luke Skywalker and another patch that responds to Yoda, and these two patches overlap, meaning that some of the neurons that fire are common to both memories. Similarly, neurons for Jennifer Anniston and for Lisa Kudrow may also overlap. However, there may be little or no commonality between the sets for Lisa and Jennifer from Friends and the sets for Luke and Yoda from Star Wars.

What does this all mean? Surgical removal of the hippocampus leaves the patient still able to recognize people and objects, and to remember events, but the patient can no longer make new, long lasting memories. It was as though the means of transferring from short to long-term memory had been removed, as if the “memory folder index” had been erased.

So, the Jennifer Anniston neuron was not necessary to recognize the actress, or to remember who she was, but it was critical to bring her into awareness for forging new links and new memories about her, such as later remembering seeing her picture.

Memories are more than single isolated concepts. A full recollection of a single memory episode involving a person or thing — perhaps even a place — requires links between different but associated concepts. If two concepts are related, some of the neurons encoding one concept may also fire the other one. This hypothesis suggests how the neurons in the brain encode association.

> “The tendency for cells to fire to related concepts may indeed be the basis for the creation of episodic memory (such as the particular sequence of events during an encounter) or the flow of consciousness moving spontaneously from one concept to another… A similar process may also create the links between aspects of the same concept stored in different cortical areas, bringing together the smell, shape, colour and texture of a rose.”
> — (Quiroga, Fried and Koch, 2013).

If the research is justified, an elusive aspect of the flow of human consciousness may have been explained. There are implications here for the memory systems, not only of humans, but also of autonomous machines, which will also need to associate concepts. An autonomous (robotic) peace officer[12], for example, would need toestablish concepts of people, places and things[13] on “his” beat, together with episodic concepts of misdemeanours and crimes in progress. He would recognize individuals with past records and observe their behaviour, comparing it no doubt with models of acceptable behaviour, threatening behaviour, etc…

Observation. The above is cutting edge research, and holds out exciting prospects, not only for understanding how memory and perhaps even consciousness function, but also for conceiving advanced computing systems that learn about concepts and association between concepts for themselves.

---

[12] Sometimes used as a hypothetical test case…

[13] As does a human peace officer.

Homeostasis

Homeostasis, dynamic equilibrium, is maintained in the body partly by negative feedback processes, and partly by dynamics in open systems. A biologist, Ludwig von Bertalanffy, developed general transport equations for open systems (Bertalanffy, 1968) as follows:

$$\frac{\partial Q_i}{\partial t} = T_i + P_i$$

Where:

- Qi = is a measure of the ith element of a system.
- Ti = the velocity of transport of Qi at that point in space.
- Pi = the rate of production or destruction of Qi at a certain point in space.

A system so defined may have three types of solution: first there may be an unlimited growth in the system, Q; second, a time independent state may be reached; and third, there may be periodic solutions.

In the case where a time independent solution is reached:

$$T_i + P_i = 0$$

In these two simple equation can be seen both the conservation laws of physics and the open systems stability of organisms.

An everyday example of the general transport equation might consider how a person maintains his or her weight, by eating as much food energy as is expended in basal metabolism, activity and exercise. This is homeostasis.

Control through feedback

While open system dynamics may be the principal means of establishing and maintaining homeostasis in natural open systems, many incremental feedback systems are also at work. Two well-known processes follow; one for maintaining blood sugar level, and the second for maintaining core body temperature. This ubiquitous “opposing pairs” arrangement in natural systems is curiously at odds with engineering and cybernetic practices.

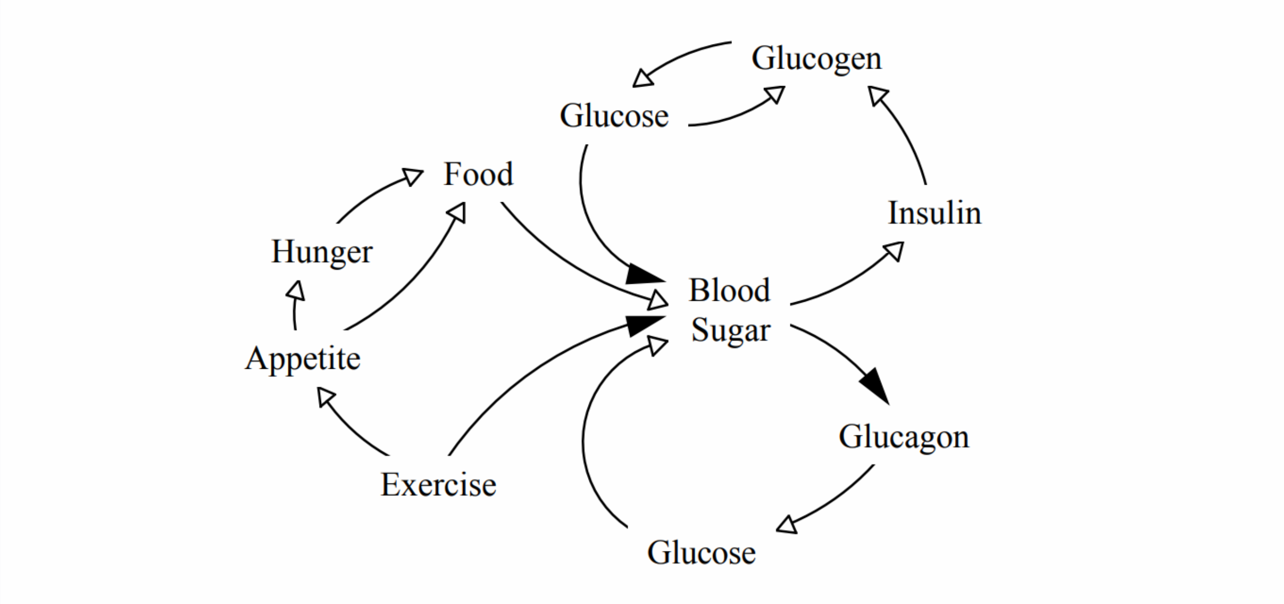


Figure 5: Maintaining blood-sugar level. Open headed arrows indicate positive, supporting relationship. Solid arrows indicate a negative, detracting relationship. E.g., increasing blood sugar level increases insulin secretion (open arrowhead); decreasing blood sugar level increases glucagon secretion (solid arrowhead).

Figure 5 presents a simplified causal loop model (CLM) showing how blood sugar level is usually regulated in the human body. The upper loop is well known: excess blood sugar caused, perhaps, by eating, stimulates the secretion of the hormone insulin principally by the pancreas, which allows glucose in the blood to be converted to glucogen (and possibly to fat) in the liver and muscles, so restoring the correct blood sugar level.

The lower loop works differently. Sustained physical exercise (or starvation) might cause the blood sugar level to drop. This is also detected in the pancreas, which secretes a different hormone, glucagon, which increases (restores the level of) glucose in the blood. Together, these elements within the body's endocrine system maintain a steady level of blood sugar in a healthy human, although that level may change throughout a typical day.

At left in the figure above is shown the relationship between exercise and food ingestion, which forms part of the energy transport equation for open organic systems. In this instance — and generally — open system dynamics operate in conjunction with the feedback controls to maintain homeostasis. The complex human system also has feedback mechanisms, not shown, which encourage eating when blood sugar falls, and when food is not needed but is expected as a result of regular, habitual feeding, as opposed to eating when hungry.

Figure 6 is a second causal loop model, showing a different pair of contra-acting causal loops. The upper loop shows the well-known effect of being in a hot environment: perspiration leads to evaporation cooling to maintain core body temperature. Less well appreciated, perhaps, is what happens when the body experiences a cold environment and the surface skin and flesh cool. As the lower loop indicates, blood capillaries near the surface contract, closing off the flow of warm blood near the skin surface, so that the blood is not cooled so much. Flesh with the blood withdrawn (or not circulating as after death) forms an effective insulator, so that heat conduction through, and radiation from, the skin surface are also reduced.

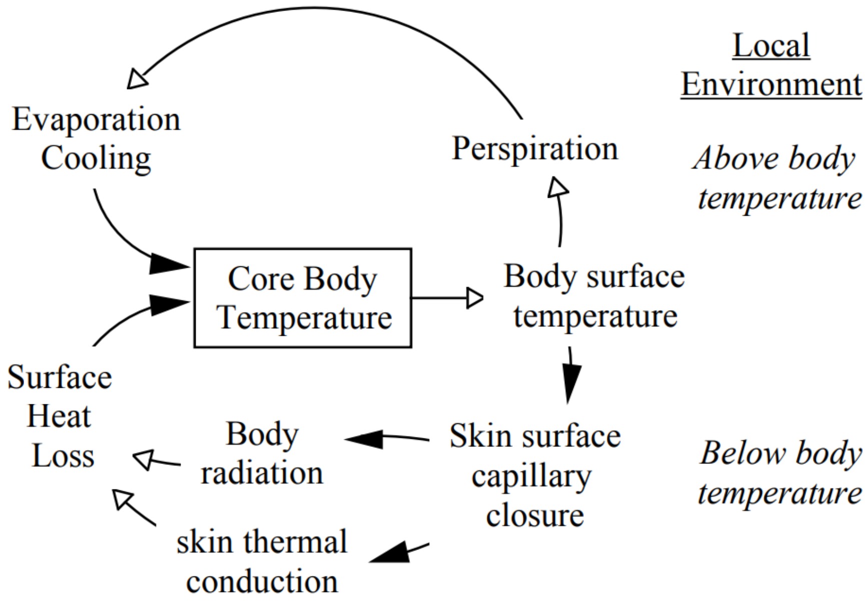


Figure 6: Maintaining core body temperature.

The combined effect of these is to maintain essential body core temperature, at the expense of a cold surface skin. As in the previous figure, we see two contra-acting causal loops resulting in maintenance of a stable value of blood sugar and core body temperature respectively. Homeostasis is established and maintained with many such contra-acting feedback loops and with the open system dynamics presented earlier.

Observations. Natural systems such as the human body clearly find it advantageous to maintain open system homeostasis by maintaining an equable inflow/outflow regime of energy, material and information, but also by controlling short-term variations using contra-acting, incremental feedback control “mechanisms”.

There appear to be advantages in this approach compared with the usual single-loop negative feedback technique used by engineers and cyberneticists. Equable inflow/outflow regimes allow the organism/platform to maintain homeostasis even when feedback control mechanisms are prejudiced, by changing behaviour and/or environment.

Some of these abilities are peculiarly human; we are the only members of the great apes to have subcutaneous fat, for example. This feature of human physiology may have evolved to sustain human hunters during long hunting trips where it was necessary to pursue prey over many miles under the heat of the African plains. It offers an explanation, too, for the naked ape's loss of hair covering; hair and subcutaneous fat together would have caused bodily overheating, so with fat being essential to sustain energy for the hunt, hair covering the whole body became prejudicial to survival. (Morris, 1967).

Social insects and social organization

The social insects are often described as "super-organisms". Certainly, hives, colonies, armies, etc., do behave in a highly coordinated manner. But then, so do trained and disciplined human armies: would we describe them as super-organisms? Bertalanffy (1968) introduced the term "organismic analogy", suggesting that human systems (teams, groups, nations, even civilizations) are not organisms, but in many ways behave as though they were organisms. The organismic analogy works in both directions: human to insect; and, insect to human. So, a hive of honeybees is evidently not a single organism, but in many ways behaves as though it were… a human city is not a single organism, but in many ways it behaves as though it were.

Hymenoptera, honey bees

Honeybees include the well-known European honeybee (Apis mellifera), which often nest inside hollow trees. (Raina & Kimbu, 2005). They construct vertical wax combs with individual hexagonal cells for storing honey and rearing brood. Each hive is "ruled" by a single Queen whose only job is to lay eggs. Workers are adult females — daughters of the Queen who mates initially with between perhaps as many as fifty male drones, stores their sperm in her body and uses it throughout her life to fertilize eggs. There are, then, as many as fifty lines of workers in each hive. Their duties change upon the age of worker bees in the following order:

Clean their own cell after eating through their capped brood cell:

- Feed brood.
- Receive nectar.
- Clean hive.
- Guard hive.
- Forage.

Some workers engage in other specialized behaviours, such as:

- “Air conditioning,” using their wings to move air through the hive to prevent overheating;
- "Undertaking," removing corpses from inside the hive.

Adult workers live for about six weeks during the summer, but Queens may live for several years. During cold winters, the bees cluster together, feeding on stored food reserves and sharing their body heat. As the weather gets colder, the “ball” of bees tightens, and there is a continuous circulation of bees from the outside to the inside of the ball. This is analogous to the way chilled humans maintain core body temperature (q.v.).

The Queen secretes a pheromone to maintain calm and order in the hive. As the hive grows in numbers, there is progressively less of this pheromone to go around “per bee”. At the same time, forager bees have to go further and further afield to fetch food for the growing numbers of bees in the hive. A mature, healthy colony may grow to as many as 80,000 workers, at which point foragers may be gathering barely enough nectar and pollen to feed, let alone expand, the hive. With so many worker bees, the Queen’s pheromone becomes too diluted to maintain calm and order, and the hive may “reproduce” by swarming, with the old Queen accompanied by many bees. A new Queen, reared within the hive, will hatch out, and restock the depleted colony.

The prime directive for the colony, or hive, is evidently propagation of the species through propagation of the hive. The survival strategy involves limiting the size of each colony to that which may be supported by local resources (flora), at which point they relocate to a new area… Hives are perennial, accumulating and storing food to survive winters in cooler climes; this appears to give the hive a fast start to the new season when the weather improves. Honeybees do not employ any technology as such, but their ability to secrete wax and to create hexagonal shaped honeycombs is surely equivalent. This “technology” directly contributes to propagation, in being used to raise the next generation and to store food compactly for over-wintering.

Observations. European honeybee survival strategy contrasts with that of humans, who build ever-bigger and more densely populated cities. Humans create complex import-export systems to transport foodstuffs from far and wide, making their cities potentially vulnerable to breakdown in supply chains, as well as supporting populations beyond that which could reasonably be supported from locally resourced supplies. This is surely a recipe for unbounded population expansion (and eventual disaster), which is what humanity is experiencing, but which honeybees avoid by living within their neighbourhood resources, and by limiting hive population to that which the local flora will support.

Hymenoptera, ants

Ants share a common ancestor with wasps, and there are over 8,800 species. (Höllobler & Wilson, 1990.) A typical nest contains at least one fertile egg-laying Queen, hundreds or thousands of adult female workers, a nursery for rearing eggs, larvae and pupae, a storage area for food reserves, and a disposal site for waste and dead bodies.

The size of most ant colonies is limited by their ability to forage sufficient food. Leaf cutter ants may establish lengthy supply chains to bring in their food source — although they do not eat the leaves they harvest, most of which are poisonous. Instead, they use them to feed a farm, which grows a fungus on which the ants live, an early example of symbiosis. The fungus farm is supplied with an antibiotic covering farmworker ant bodies, so preventing disease; these ants discovered antibiotics some 40M years ago.

Army ants are carnivorous nomadic predators that form bivouacs, but do not nest. Honeypot ants farm aphids, living on their excreted honeydew and moving them from plant to plant as a farmer might move cows between pastures.

Recently results from an interesting 6-year[14] study, publicized by Professor Laurent Keller, Director of Ecology and Evolution at the University of Lausanne, Switzerland, have shown that ants have a similar allocation of worker duties with age to honeybees:

- Young ants, about one third of the workers, were nurses.
- About a third were cleaners, having graduated from nursing.
- And about a third were foragers, collecting food outside the colony, having graduated from cleaning.

Researchers found that ants, with lives lasting about a year, tended to socialize within their current ‘profession,’ e.g., nurses with nurses, foragers with foragers. It was not clear what promoted ants from one profession to the next, nor was promotion automatic: researchers found occasional old nurses and young foragers.

Observations. Between them, the many and various ant species display a wide variety of lifestyles and survival strategies. Some are carnivorous, some vegetarian. The biomass of all ant species in the world is reputed to exceed that of all humans[15] Throughout, their prime directive is survival of their species; they limit their nest/colony size according to locally available resources, a repeated lesson, perhaps, for humans.

---

[14] Read more at http://www.dailymail.co.uk/sciencetech/article-2311688/ANTS-change-job-grow-older-scientistsdiscover.html

[15] See en.wikipedia.org/wiki/Biomass_(ecology), extracted April 2013)

Blattodea (formerly Isoptera), termites

Termites share a common ancestor with cockroaches, and are universally vegetarian. (Darlington & Bagine, 1999.) Although similar in appearance to ants, they are unrelated, another instance of convergent evolution solving the same social problem. There are some 2,600 known species of termite. They eat anything from lichen and fungus to wood.

In Africa, termites create enormous mounds, with funnels to create air conditioning, particularly for the Queen's chamber, which is held at 30˚C and near to 100% humidity – not dissimilar to the breath of a mammal. These mounds can become very large, with some 35km of tunnels. The relatively huge Queen may live up to 30-45 years, supported and enabled by her king who remains virtually attached to her as she continues to lay eggs. There may be over one million termites in a mound, with the Queen as mother to all.

Like other eusocial insects, termites have castes:

- Reproductives.
- Workers.
- Soldiers.

Periodically, members of the winged sexual caste take to the air, mate, and the newly fertilized young Queen seeks a new spot where she may start a new colony. So, new colonies are budded off the old, but — unlike honeybees — the old may stay put with its original Queen.

Observations. Termites, at least African termites, may be more established than their ant and bee "cousins", and they build strong, deep nests, mostly underground. Queens 'entertain' their king, and together they are much longer lived. Like the Hymenoptera, they live very much within their neighbourhood, foraging over the surrounding surfaces, clearing up vegetable detritus, advantageously reducing the risk of forest fires in the locale.

Do we have anything to learn from the social insects?

Insect societies are inherently different from human societies. We humans would find insect social behaviour intense, exceedingly tiring and beyond our ability or desire to sustain. Busy bees, for instance, literally work themselves to death. The social insects know instinctively what job they are intended to do, and they do it: no instructions, no supervision — although, failure to perform may result in summary execution.

Much of the social insects' apparent decision-making is democratic, with insects voting in preference for one option over others, as with the bees and the famous waggle dance, where the "strongest waggle" wins. There is no control, as such. Neither is the Queen in charge, in any conventional sense; that is surely an anthropomorphic viewpoint.

There are, however, castes. While all eggs may be laid equal, the way in which they are fed may produce morphologically different results, castes:

- Bees and ants have worker and reproductive castes (Queen and drone). Workers tend to progress from nursing, though cleaning to foraging. Some ant species have soldier castes where the soldiers are very much larger than the workers, and may have to be fed by those workers.
- Termites have reproductive, soldier and worker castes (immature males and females (nymphs), with potential to moult into replacement soldiers or "reproductives" if needed. Soldiers may differ from others morphologically, with "hoses" on their heads to squirt irritating fluids at their enemies — often ants…

Castes may be compared with classes in human society, which have existed since the earliest times — the earliest probably being that of ancient Egypt. This isolated proto society was a "pyramidal" (sic!) three-class system of a pharaoh and a few upper class nobles ("nomarchs"), a middle class of merchants, lawyers, priests, schoolteachers, doctors, scribes, etc..., and a working class of very many who used their hands to till, fish, grow, tend, operate and make things. Despite efforts to eradicate, reclassify and rename class, it is still with us and seems to be as innate within human social order as it is within insect social order.

Class mobility, on the other hand, the ability to move between classes, is evident within the social insects, except where caste is morphologically determined. Within the social insects, workers progress through "professions", finally working outside of the colony/hive as foragers. Within human society, there is no such obvious progression… although as humans age in society they tend to accumulate knowledge and experience, (may) gain social stature, (may) own property, etc. It is not really the same…

The eusocial insect example suggests that a contemporary Western idea, that all people should be essentially equal[16], may prove difficult to achieve. People naturally fall into classes and castes: some are leaders, some followers, some develop quickly, others more slowly, and some develop degrees of social sophistication with age and experience. Attempts to destroy/discredit so-called upper classes (determined by inheritance, wealth, education and ownership) results in the creation of pseudo classes, such as celebrities — people who seem to be celebrated more for ridiculous, disgraceful, socially unacceptable behaviour than for anything meritorious.

---

[16] Promoted by various political notions such as Political Correctness, feminism, equal opportunities, 'gay' equality and marriage, etc...

All of the eusocial insects create societies that are closely related genetically, to promote cooperation and coordination. Humans have no obvious equivalent, outside of the family group, nor would we want or accept one. But do we have any corresponding attributes that would similarly promote cooperation and cooperation? Perhaps it would be easier with human society to identify those phenomena that prevent, or detract from these “desirable social traits”.

- **Culture.** People of different cultures, upbringing, educational backgrounds, political persuasions, religions, etc..., may behave, express attitudes and formulate decisions that differ from each other, so constraining cooperation and coordination
- **Belief systems.** Our view of the world, our Weltanschauung, and our beliefs — cultural and religious — may differ radically from others, so that we are unable to see things as they do, and vice versa.
- **Training.** Intense military-style training may overcome different belief systems, such that people who have trained together will cooperate and coordinate in their actions, decision-making and will even overcome their differing natural reactions under pressure.

So, we may reasonably expect human societies where people are the same/similar background, culture, education, upbringing and beliefs to form cooperative, coordinated societies. Within those societies we may expect to find different classes. And this is generally, although far from always, the case.

Alternatively, cooperative societies may form and self-sustain where culture encourages individuals to consider themselves part of a close-knit family group. (Toyota in Japan has operated in this way, with notable success. (Womack, 1990))

What price, then, multi-cultural society? If the eusocial insects are to offer any guidance, it might be that an effective, coherent multi-cultural society is unlikely, while a complex of different side-by-side discrete cultures is more likely, with the inevitable risk of friction at the cultural boundaries.

Conclusions

Biomimetics offers a wide range of models from individual organisms and from the social insects, which may be of benefit to systems, systems thinking and systems engineering. Comparing natural and human systems engineering suggests that human systems engineering parallels natural systems engineering to a surprising degree.

Further that, in both instances, systems engineering appears fundamentally to be the integration of functional structures from one level of organization lower — although integration may be far from simple…

Natural systems employ a more sophisticated approach to homeostasis than do engineers and cyberneticists. Nature's methods generally involve contra-acting control loops providing incremental regulation of open system "flow through" of energy, substance and information: they are robust, non-linear, fast, precise, effective and tested by time. There may be much to learn here.

Natural systems employ a more sophisticated approach to homeostasis than do engineers and cyberneticists. Nature's methods generally involve contra-acting control loops providing incremental regulation of open system "flow through" of energy, substance and information: they are robust, non-linear, fast, precise, effective and tested by time. There may be much to learn here.

Social insect societies remind us that the prime directive of all animals is the propagation of species. For hives and colonies it is quite evident that their "business" is to raise the next generation; that is what they are preoccupied with doing, and what their equivalent of technology is dedicated toward.

Many — most — human societies, on the other hand, seem to be unaware of this prime directive, leaving people to question "the purpose of life", to devote their lives to accumulating wealth, to hedonism, to being continually entertained by their governments, to devote themselves to war, conflict, sport, business, work, music, etc., to decide not to have children, and many, many more ways of denying, overcoming, or supressing their nature and ignoring the prime directive. Despite this — or, perhaps because of it — human population continues to rise…

The eusocial insects suggest that human societies should be able to manage population size much better than we are presently doing. The hive, the colony, etc., limit their population to that which can be supported by the immediately surrounding flora and fauna, according to species. If there is insufficient food, they do not continue to multiply, but instead they swarm, or bud off, another hive or colony in another areawhere the resources are adequate.

The eusocial insect example does suggest that countries, or regions within countries, could easily establish whether or not they are under-populated or overpopulated.

- A place (village, town, city, nation) would be overpopulated if the existing population absorbed more resources than the immediate surrounding environment was actually providing for human consumption.
- Similarly, it is possible in principle to draw a circle around centres of population, with diameter sufficient to encompass the actual, productive farmland area needed to support that population: i.e., the "food resource footprint".

As a non-political observation, such concepts challenge globalization that would see populations growing unchecked, supported by global exports and imports — inevitably leading to further overpopulation… Social insects also differ from humans in maintaining their essentially agrarian lifestyle; many humans, on the other hand, have abandoned the land physically, socially and mentally, encouraged by the Industrial Revolution, which still rumbles around the planet. As human populations continue to grow and has to be fed, however, it seems possible that there will be, of necessity, a general return to a more agrarian lifestyle for many, if only to feed themselves and live in balance with, rather than progressively destroy, their supporting local environments.

Social insects also entertain class and caste, concepts that politicized western societies find objectionable. If human social history and the social insects are to be appreciated, class and caste are inevitable; attempts to demolish class will serve only to see class re-emerge under different headings. Certainly the present situation in some western societies, where it is somehow despicable to be of a high social status, wealthy and well educated, is inverted. Should we all not, rather, aspire to be like that than to denigrate it, supplant it with highly doubtful celebrity status, and degrade society in the process? Although few of us, perhaps, would want to emulate the social insect Queen, with nothing to look forward to but spending more years producing ever more eggs…

References

- Bar-Cohen, Yoseph, (2011) “Biomimetics: Nature-based Innovation,” CRC Press
- Benyus, Janine, M, (1997) “Biomimicry: Innovation Inspired by Nature,” William Morrow
- Bertalanffy, Ludwig von, (1968) General System Theory: Foundations, Development, Applications, New York: George Braziller, revised edition 1976
- Darlington, J.P.E.C. and Bagine, R.K.N. (1999) Large termite nests in a moundfield non the Embakasi Plain, Kenya (Isoptera: Termitidae), Sociobiology. 33: 215-225.
- Höllobler, B. and Wilson, E. O. (1990), The Ants, Springer-Verlag
- Howard, E (1902), Garden Cities of To-morrow (2nd ed.), London: S. Sonnenschein & Co,
- Kazlev, et al., M. Alan (2003-10-19). “The Triune Brain,” KHEPER. Retrieved 2007- 05-25
- Markram, H, (2012), “The Human Brain Project,” Scientific American, 306.6
- Morris, Desmond, (1967) The Naked Ape: A Zoologist's Study of the Human Animal, Jonathan Cape, UK

- Quiroga, R. Q., Fried, I., and Koch, C., (2013) Brain Cells for Grandmother, Scientific American, 308.2
- Raina, S. K. and Kimbu, D. M. (2005), Variations in races of the honeybee Apis mellifera (Hymenoptera: Apidae) in Kenya International Journal of Tropical Insect Science. Vol. 25.4 pp.281-291.
- Womack, J.P., Jones, D.T., and Roos, D (1990) The Machine that Changed the World, Rawson Associates, NY

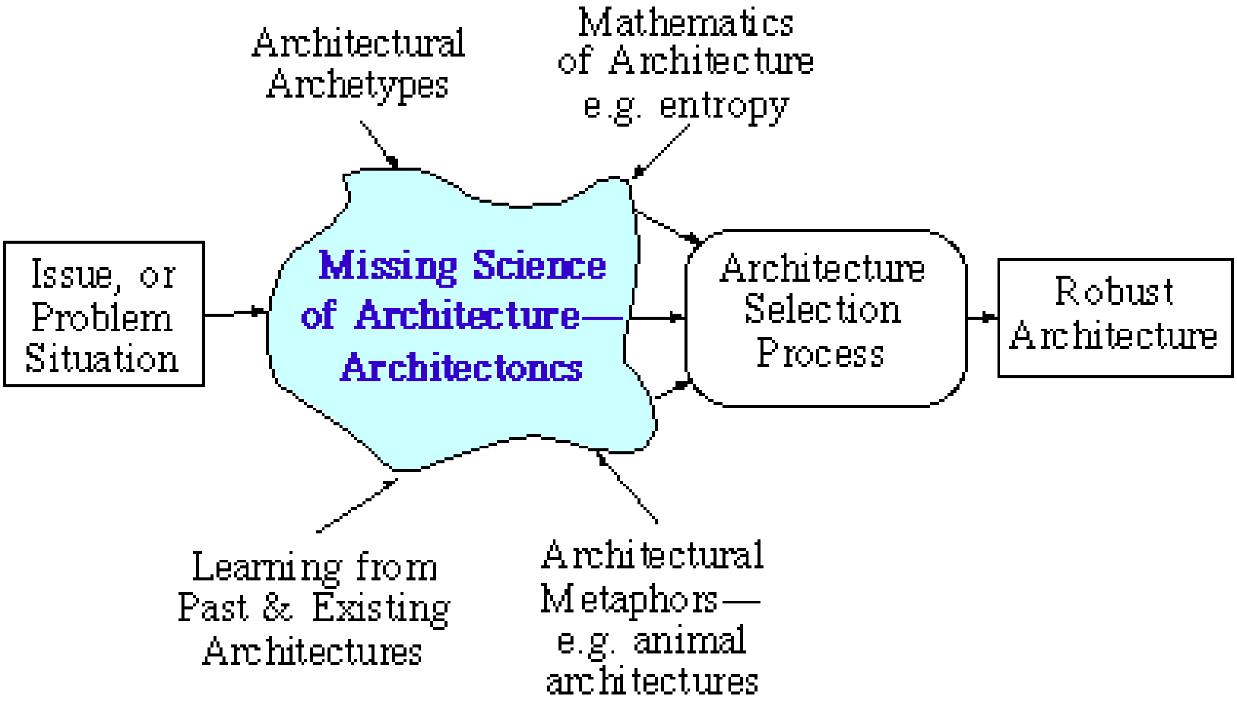
System engineering architectonics

what is systems architectonics? It describes a subject which barely seems to exist — the study of systems architecture. It seems that we presently lack the ability to examine a situation and then prescribe a systems architecture best suited to that situation.

The missing science

The problem is presented in the following picture, which shows the so-called missing science, and suggests sources that might contribute to it:

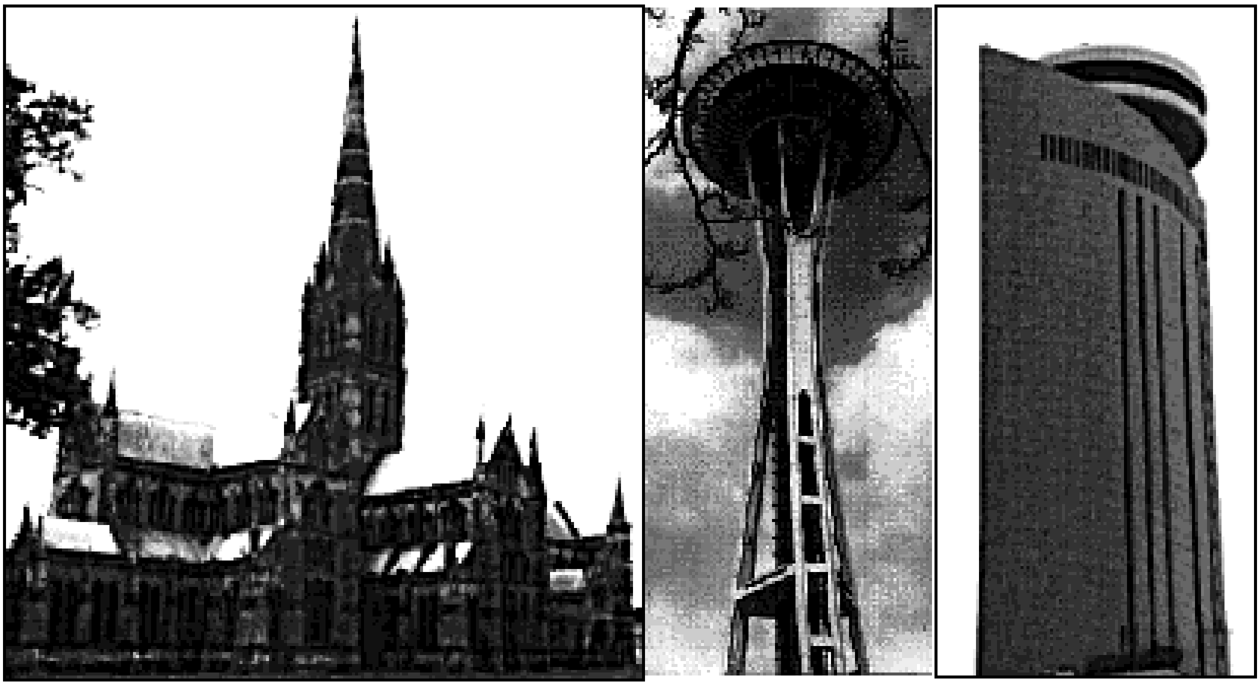
- Architectural archetypes.
- A mathematics of architecture.
- Architectural metaphors.
- Learning from past and present architectures.


Architectural Archetypes
Mathematics of Architecture e.g. entropy
Issue, or Problem Situation
Missing Science of Architecture—Architectonics
Architecture Selection Process
Robust Architecture
Learning from Past & Existing Architectures
Architectural Metaphors—e.g. animal architectures

- That's the plan — but can we do it without falling into traps such as:
  - Reinventing the wheel.
  - Making false deductions because the environment that spawned some old architecture is no longer relevant.

  - Misreading metaphors.
  - Etc...

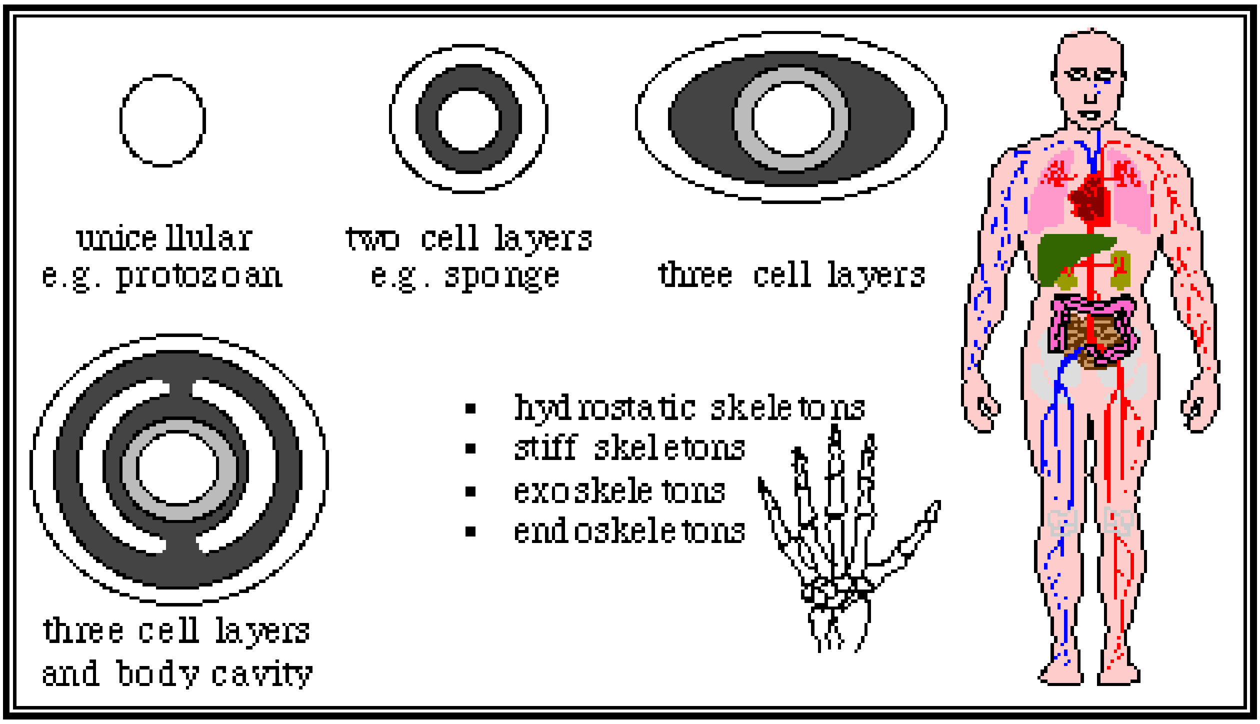
Aspiring architectures



At left is Salisbury Cathedral, centre is the Seattle Expo tower and right is the Forte Grand, Abu Dhabi:

- The buildings nations produce exhibit features consistent with their national development and contemporary psyche, indicating confidence, severity, retrenchment, exuberance...
- Young, confident societies/civilizations create monuments to their future, reaching to the sky. Buildings tend to be massive, but with purity and severity of line, e.g. pyramids, cathedral spires, Eiffel tower...
- Wealth creates architectural variety. Impoverishment results in architectural monotony.
- Poor/demoralized societies do not build monuments to a future in which they have no confidence. Nor do they invest in infrastructure to connect and bind their societies together. Through the ages, and today, architecture is a barometer of societal psyche.

Animal architectures



The figure shows several different animal architectures — see Cambridge Encyclopedia of Life Sciences. As the architecture becomes more complex, both advantages and problems arise:

- Animals become better able to accommodate different environments, process different resources, remain viable between meals, etc...
- Energy distribution and waste collection, instead of simply occuring through a cell wall, require canals, arteries, etc...
- Heat generated in the centre is less well able to escape.
- Etc…

It soon becomes evident that, as architectures become more complex, waste disposal becomes a significant issue.

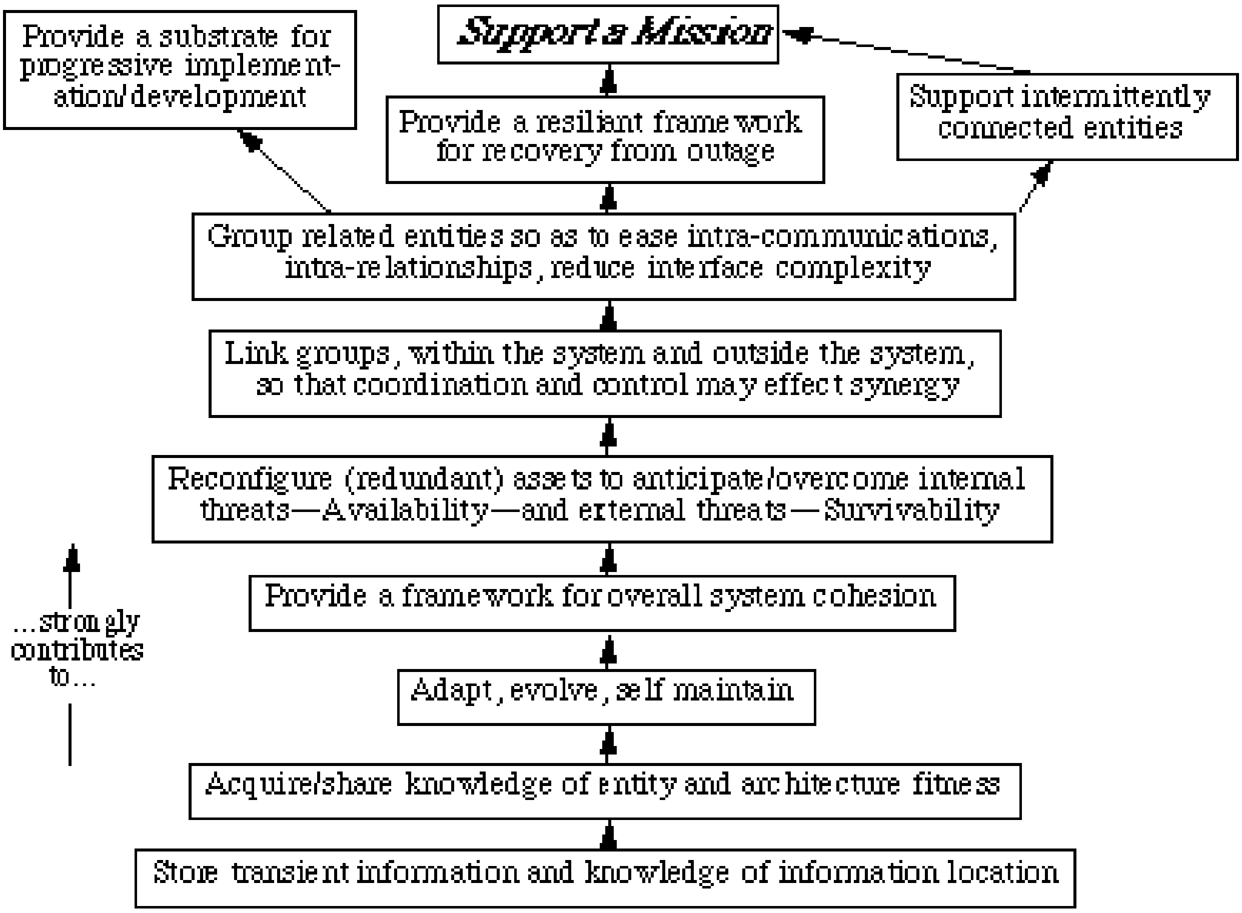
Scaling of architectures becomes problematical, too. While the surface of exoskeletons increases with the square of their radius, the volume (and weight) contained increases as the cube of the radius. Result? Beyond an uncertain size limit, exoskeletons are ineffective.

Humans have developed a composite skeleton. While most of our skeleton is internal (endoskeletal), our brains are protected by our skulls, effectively an exoskelton. Similarly, our rib cage protects our lungs and softer organs within. Here, the rib cage is an incomplete exoskeleton to reduce weight and increase flexibility.

With a little thought, it can be seen that these "rules" through which animal architectures have evolved can be more generally applied:

- Waste management is crucial.
- Architectures do not scale.

Architecture's mission


Support a Mission
Provide a substrate for progressive implementation/development
Provide a resilient framework for recovery from outage
Support intermittently connected entities
Group related entities so as to ease intra-communications, intra-relationships, reduce interface complexity
Link groups, within the system and outside the system, so that coordination and control may effect synergy
Reconfigure (redundant) assets to anticipate/overcome internal threats—Availability—and external threats—Survivability
Provide a framework for overall system cohesion
...strongly contributes to...
Adapt, evolve, self maintain
Acquire/share knowledge of entity and architecture fitness
Store transient information and knowledge of information location

- Architecture expresses purpose in man-made systems — architecture is the structural framework giving form and substance to a system, but architecture is more — by its very form it expresses viewpoints, contains information, affords adaptability to new purpose, marks territory...
- Examining the architecture of evolved buildings suggests a set of attributes which could be expected of successful architecture for any kind of modern system.

- Using Interpretive structural modelling, these various objectives can be formed into an objectives "tree" or attribute enhancement structure.

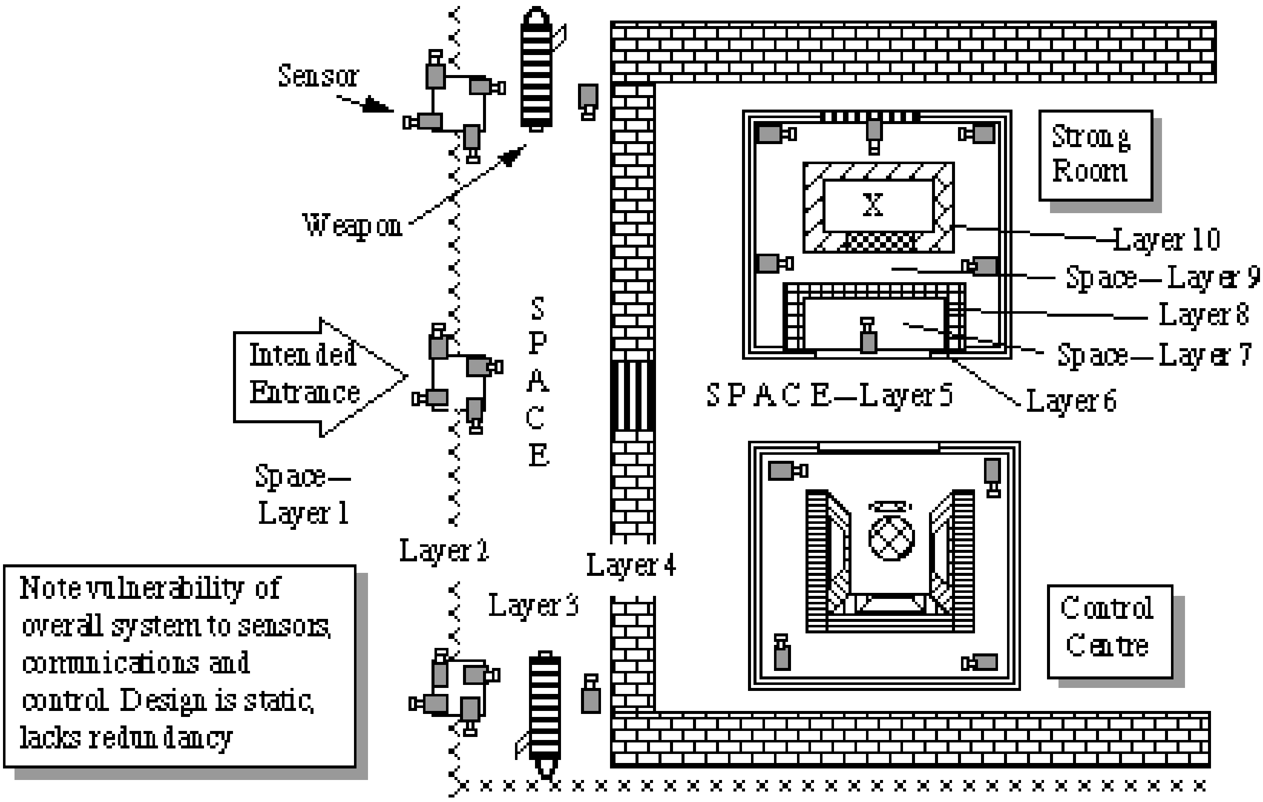
Kinds of architecture

- Appears in many forms, with decoration sometimes concealing much underlying structure.
- Structure offers two main archetypes:
  - Layered architectures, enabling or resisting passage through a structure comprised of successive layers, perhaps undergoing transformations, and finally exiting. This is the basis of process oriented architectures used in manufacturing, communications, defence and security, trees and plants, the Sun, alimentry canal…
  - Clustered architectures, where architectural components form into groups, perhaps with a view to reducing energy of, or time taken for, interaction between the components. This is the basis for architectures used in human organization, circuit board and microcircuit design, some evolved biological designs, topics in textbooks, parts stored a warehouses, ethnic restaurants, books in a library…
- In many systems, layers form as a result of clustering.

Layered architecture

Method used since pre-history is the layered defence:

- Instead of a single, eggs-in-one-basket, barrier, several barriers in succession.
- Each layer need not be perfect.
- No single barrier responsible for all neutralization.
- Attackers/intruders faced with time-consuming series of hurdles.
- intruders exposed to detection/attack for longer, presenting greater threat of detection.
- intruders must carry variety of tools/weapons/etc..., to tackle each (different?) layer of defence.
- Bona fide entrants less inconvenienced.
- in multi-layered system, each layer need not be so demanding.



- The figure shows a typical high security area, with fences, sanitized zones, automatic cameras, even weapons (unusual in most countries, but not unknown worldwide.)
- There are some ten layers — note that a sanitized zone is a layer, as well as a fence.

Layered architecture and mathematics

$$\boxed{P = 1 - (1 - p)^N}$$

where…

p…is the neutralization probability per layer

N…is the number of layers

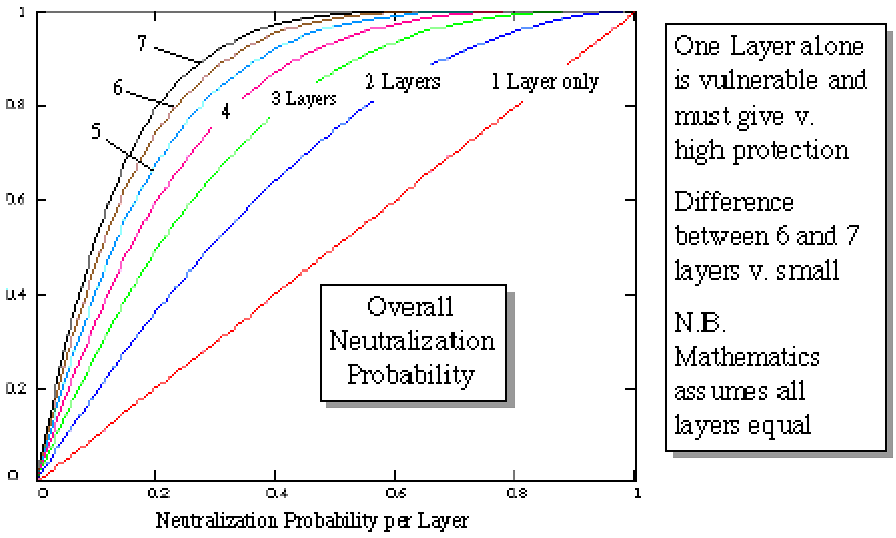
P…is the expected overall Neutralization

N.B. Assumes all layers have equal p

(1-p) is the *leakage* probability per layer

The simple equation addresses the probability of passing through a series of N layers one after the other, each having the same probability of neutralizing, i.e. of preventing further passage.

The equation produces the following graph:



Overall Neutralization Probability

One Layer alone is vulnerable and must give v. high protection

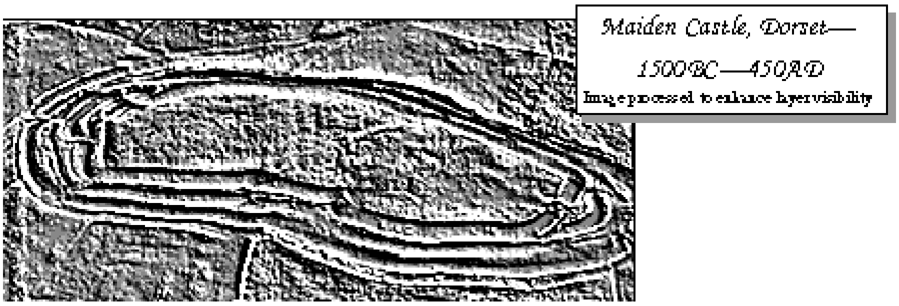
Difference between 6 and 7 layers v. small

N.B. Mathematics assumes all layers equal

Looking at the graph, it soon becomes clear that the lines for successive layers are getting closer together. Evidently, there is some law of diminishing returns at work.

- If you have one layer, then a second gives a great benefit.
- If you have 6 layers, then an extra layer confers much less additional benefit.

The cost, in terms of effort, in adding each additional layer, may soon prove prohibitive. Consider Maiden Castle:



Maiden Castle, Dorset—

1500BC—450AD

Image processed to enhance hypervisibility

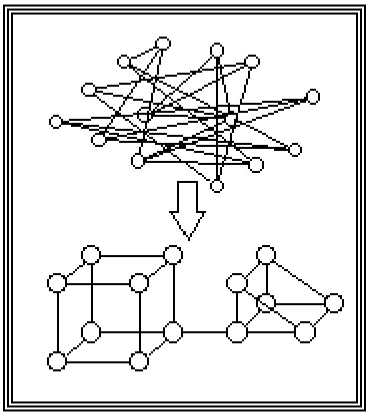
- Counting earth ramparts, Maiden Castle had 5 layers of defence.
- Counting ditches between ramparts too, there were 11/12.
- Note at left and right ends, the additional earthworks guarding the entrances — always a weak point.

To a first approximation, the circumference of each ring goes up as the square of its radius, so each successive ring going outwards from the centre must take significantly longer and cost more.

Add to that the diminishing return for each new ring, and it soon becomes evident that there was a strong pressure to have the "right" number of rings, where right means that the rings provided effective defence at an affordable cost.

Clustered architecture

- Systems architecture can be thought of as the organization and grouping of things for some purpose. Architecture, then, is servant to some higher purpose.
- Systems engineering architecture tends to afford the foundations of performance, rather than aesthetics.
- Often, exchange of energy, substance or information between parts within a system easier/uses less energy/faster, if distance between parts is shorter.
- Moving two parts closer to each other to improve exchange extends other links — hence some optimum arrangement improves overall performance.
- That is systems architecture design - finding the optimum for whole system, not just some parts.

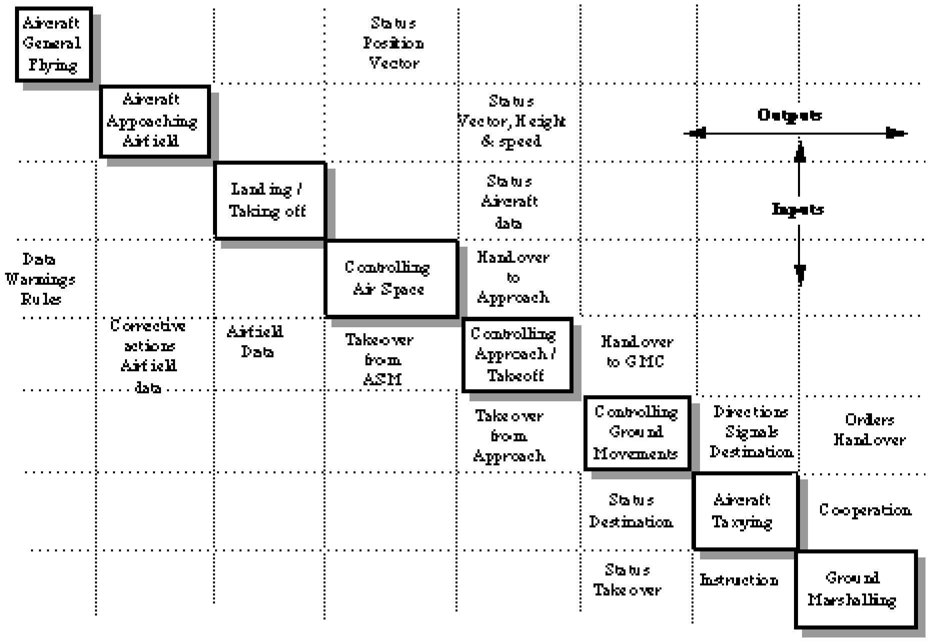


- In going from the upper to lower diagrams, a degree of order has been introduced — or, if you prefer, entropy (the measure of disorder) has been reduced.
- The entropy reduction is real. In the two figures, the sum of all the link-lengths joining the entities is greatly reduced in going from first to second figure. This shortening equates to untangling, hence to real entropy reduction.

For clustering, consider:

- The value derived from clustering depends on the nature of the system whose parts are clustered.

- Where there is advantage to the overall system from reduced time or energy utilization in the interchanges between internal parts through internal infrastructure, then advantage may accrue from reduced overall link-length. This condition pertains for many systems but not for all.
- Advantage may also accrue from proximity between some parts of one system and interacting parts of another system. In such cases there may be a trade-off between internal advantage and overall advantage.
- e.g. Analysis of aircraft under ground control shows that control reliability would improve if aircraft and controller were co-located. This is impractical. Hence an alternative strategy emerges — the provision of high-integrity, redundant communication channels between aircraft and controller.



From the N2 chart, note the following:

- There are two functionally bound blocks, one for airspace control and one for ground movement control.
- There are three connected control centres.
- The approach and take-off control is at the centre of a "cross" of interfaces, showing it to be a vital node — if it were not there, the system would separate into pieces.
- All parts are connected, but only via one of the three controls.

Getting to grip with complexity

Preface

You do not have to look beyond the shelves of any popular bookstore to find works on the so-called theory of everything.

This hoped-for universal theory seeks to explain the fundamental forces which have shaped the universe — gravity, electromagnetic, weak, nuclear… and perhaps some forces yet to be revealed. The theory of everything would answer many of our deepest questions, it is believed, and might lead us to understand gravity, the creation of the universe, even perhaps the ultimate fate of the universe. There is much to be commended in such a search — it plumbs the depths of our limited understanding, and makes the human mind soar at the prospects it unfolds.

It is a "noble venture". And yet...

Given such a theory, would it explain our everyday experiences? Would it explain those simple, yet puzzling, phenomena, such as the seemingly-endless propensity for things to get more complicated, self-awareness emerging from the brain, or the diversity and endurance of life?

The answer seems to be "no". While the theory of everything searches for the root causes of existence, it appears to be less concerned with phenomena which emerge from the variety and interaction of things that exist. Things, it seems, can work together in so many different ways that sometimes the results are an almost incomprehensible exuberance of behaviours.

Without wishing to "put down" the noble quest for a Theory of Everything, I would suggest that it is misnamed — and to be fair, the name is one beloved more by the media than by many of the scientists involved in the search. To deal with our everyday world, we need another theory — let us call it the theory of complexity.

What would a theory of complexity be about? To be useful, it would have to help us understand how and why complexity arises, how we can react to it, how we can manage it, control it, reduce it, predict it, live with it, benefit from it, and many more.

What might a theory of complexity be about? Where might we search for such a theory? Can we, like the physicists and mathematicians, use contemporary science to probe the mysteries of complexity? Looking around the planet, we see many complex systems. As Charles Darwin noted, the profusion of life, the web of interactions that sustain life, these are exceedingly complex. Perhaps, then, we may look to the natural world as a model of complexity. After all, the natural world has evolved over some three thousand million years, with plenty of time to develop its current characteristics. In looking at the evolving natural world, then, we may find ourselves emulating those seekers after the theory of everything, since they too regress several thousand million years, by observing remote stars, galaxies and quasars. True, they can see further back than we can, and their information may at times be less confused, but there is a parallel.

Biology and ecology study today's highly evolved natural world, and many clever people have deduced, from observation and experiment, underlying mechanisms that create some sort of dynamic order. Complexity exists in our human world, too, and it would be natural for us to be concerned, even primarily perhaps, with understanding this human world of economics, politics, technology, business, organization and culture. If we start with a biological or ecological model, can we justify transferring the data from those domains to the human activity world? Do organizations behave as organisms: do economies behave as ecologies?

Clearly we have to be careful in making any such assertions. There may be parallels, but we must use them cautiously. Moreover, in many of the areas where we might be interested, clinical experimentation is not viable. Can we, for instance, experiment with the complex situations invoking genetic engineering? Can we entertain social engineering, in the sense of experimenting with people's lives? To be sure, politicians do it all the time, but the results can prove horrendous as in Russia between the wars.

On the other hand, there is no risk in developing sensible working hypotheses about our complex human existence, nor in testing these hypotheses against historical and contemporary human experience. In the real, complex world, it is often not practicable to conduct neat, clinical experiments such as those which scientists and engineers generally employ. The notion of neat experiments to address complex issues is, perhaps, a non sequitur, since the very complexity of the issue confounds the process of simplification essential to neat models and experiments. In other words, if we make the problem simple enough to model or for experiment, are we then addressing complexity at all?

Seekers after the theory of everything face not-dissimilar problems. Many of the phenomena about which they would like to experiment are galactic or super-galactic in nature, laboratory experiments are not feasible, and researchers must resort to developing theories and models which, if they behave as the observed universe, offer potential insight. There is, at the time of writing, for instance, no direct evidence for the existence of black holes, although many scientists behave as though they are real stellar objects.

Lack of experimentation is anathema to many engineers and hard scientists — perhaps that is why we lack a Theory of Complexity. On the other hand, the ubiquitous computer is coming to our rescue as new machines continually increase our ability to model more and more complexity in greater and greater detail. It is not yet possible to consider a complete representation of almost anything in a computer model. The number of molecules and their mutual interactions in a single drop of water would defeat representation in most computers. A complete computer-model of a human would have to be as complex as the human, thereby defeating the object. The complete model of a society would contain not only the complexity of each human, but the complexities of their mutual interactions, and is out of the question. Modelling of some sort, involving some abstraction, is valuable; the nature and validity of that abstraction is crucial.

Understanding complexity

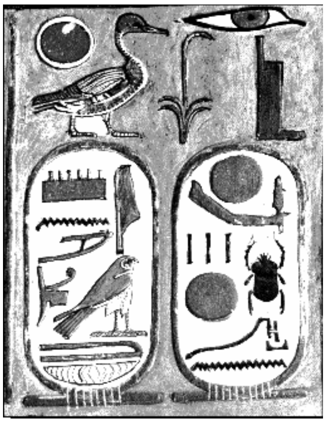
Introducing complexity

> "All theory, dear friend, is grey, but the golden tree of actual life springs ever green."
> — Johann Wolfgang von Goethe, 1749-1832

Questions of complexity

What is complexity? Is it a commodity? What is it made from? How can it be measured? How does it arise? How does complexity relate to order? Can order arise from chaos

How does chaos relate to stability and complexity?



These questions, and many others, are the substance of this book, together with one other which is illustrated by the image aside. The figure is taken from Horemheb's scrolls, to be found in his tomb in the Valley of the Kings, Luxor, Egypt. (We shall meet more from Ancient Egypt later — their highly-developed culture affords non-sensitive information, much of it relevant to today's societies). If you have not met such scrolls before, if you do not read hieroglyphics, and if you know nothing about Horemheb, then the scrolls will probably seem complex.

On the other hand, you may know that the duck signifies "son of" and that, next to the solar disc, they signify together "son of Re, the Sun-god". The eye and the two symbols beneath it, one of sedge grass and the other of a chair, signify Lord Osiris. Similarly, the left-hand cartouche indicates (approximately) "Amun loves Horemheb". This supposed devotion by the god Amun becomes more poignant when it is known that Horemheb seized the throne, rather than inherited by divine right, and had to assert his dubious god-given status.

The scrolls rapidly lose their seeming complexity as one learns the meaning and significance of their parts — that is the point. The complexity is perceived rather than real. As we shall see, complexity can be real, too. After all, is complexity any less real simply because it is (only?) perceived?

Bak & Chen's self-organized criticality

Bak and Chen researched into tectonic plate movement, seeking some pattern to earthquakes which might enable prediction. They examined models of sand dropping on to a disc mounted on a sensitive weighing machine. The grains of sand were chosen to be of similar size. As they dropped, a cone formed and grew to a critical size, above which there were slippages and below which there was a recurring build-up. Because the grains were of a size, it was possible to calculate the number of grains falling off the disc at each slippage, and a graph could then be drawn of the frequency of slips vs. the number of grains per slip. Not surprisingly, there were fewer "big" slips, with lots of grains, and more small slips with fewer grains. However, Bak and Chen also discovered that by plotting the frequency of slips of a certain number of sand grains on logarithmic scales, the data formed a straight line. The researchers refer to the phenomenon as "self-organized" because, as the cone grows above a critical size, it slips back and then grows to the same size. So long as the grains continue to fall, so long will the cone self-organize.

Bak and Chen described the relationship between frequency and numbers as "weak chaos", because it followed a power law relationship. (Chaos follows an exponential relationship). They and other researchers found that straight lines arose from other data, although the slope and start points would be different. Weak chaos has been observed in types of electronic (1/f) noise, stock exchange prices, distances between cars, deaths in war, and many more.

The Bak and Chen model is simple. Unlike many models, it is not built up from detail. One might, for instance model a sand cone by examining the characteristics of each sand grain, their angularity, coefficient of friction, stickiness, etc., and then model the way the individual grains fit together into a cone; this would be a micro model. Bak and Chen's model is a macro, or system, model; it offers description of phenomena without resorting to a build-up of complex interaction detail.

Why do so many different phenomena produce straight-line curves when plotted as above? Is there some underlying behavioural similarity between them which we have yet to uncover? What links the distances between cars on a motor way, stock exchange prices and deaths in war? Perhaps the clue comes from electronic noise in resistors. One noise model proposes a vibrating ionic lattice with electrons tumbling through the spaces, getting snagged behind ions, and forming miniature piles of electrons which then slip in groups, resulting in the familiar spectrum of noise. The key may be in the progressive build-up and subsequent slip process, as opposed to random phenomena which, by definition owe nothing to previous events.

Complexity, science and engineering

Research is revealing that complex, interacting systems can develop organized behaviour (Ruthen, 1993). Biologists, economists and physicists have been observing that complex, open, interacting systems evolve toward a boundary between order and randomness.

The subject which combines the interests of such diverse sciences is non-linear dynamics, and computer models of such systems can exhibit bizarre behaviour so that words such as chaos, anti-chaos, fractal and strange attractor have entered into everyday usage.

Conventional science and engineering have some difficulty with this macro/open-system behaviour. Engineers seek to control, to create order, to address linear problems where their mathematics can work. When their created systems interact with a complex world, results may prove counter-intuitive. Understanding complex system behaviour is essential to improve both scientific and engineering performance, but these notions have made little impact on many pragmatic (and successful) engineers.

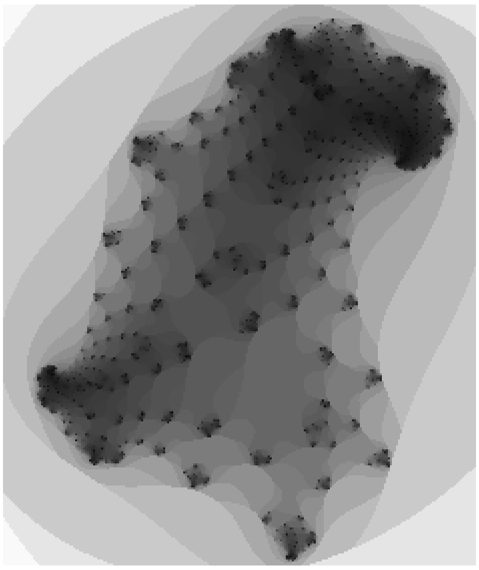
Some complex systems seem very robust compared with their "engineered" counterparts and far-sighted engineers ask questions. For example, planned economies seem to be very sensible. They plan ahead, set reasonable targets, provide contingencies against risks or disasters, develop alternative sources and markets, yet they do not seem to survive. The evidence clearly favours survival in a free market, where much of the control is taken away, where competition is encouraged, where co-ordination between the various parts is minimized, where the law of the economic jungle applies.

These are the very conditions industry and its engineers seek to avoid within their own organizations and designs, in the name of increased efficiency, effectiveness and quality.

Engineers in aerospace, particularly, have recognized complexity as an issue. Systems, they say, are inexorably becoming more complex to meet ever-more demanding customers; the task of engineering is seen as managing that increasing complexity. Is complexity the fault of customers' demands? Come to that, is complexity "good", "bad", or immaterial?

Components of complexity?

We know, from everyday experiences, when something is complex. A tangled jumble of wool is more complex than a neat ball. Snooker and pool are more complex than billiards, because of the various colours and their individual scores. A formula 1 racing car engine is more complex than a model T Ford engine because of the greater variety of parts all doing their bit to improve performance. On the other hand, there is nothing more complex about twenty identical paving slabs than about ten; it is not the number of things alone that makes for complexity.



There seem to be three components of complexity:

- **Variety**
- **Connectedness**
- **Disorder**

Something is more complex if there is greater variety amongst its components, if the number of connections between the components is greater rather than less, and if the variety and the connections are mixed and tangled-up, rather than orderly. Following topics will explore each of these components in turn.

Variety

> “Variety's the very spice of life, that gives it all its flavour”
> — William Cowper 1731-1800”

Variety is a major component of complexity. Variety can be viewed as a commodity, of which we can have more or less. For systems to be stable, they may need a minimum variety: to adapt, they may need useful variety. Excess variety may change the nature of system behaviour.

Generation of variety

Looking to the natural world, we see that the profusion of species, plants and animals, or "speciation", is greater in more energetic systems. For example, bio-diversity is much greater in a rain forest than in cold tundra areas. Is it too great a leap to note that car variety, the profusion of car makes and models, is greater in New York, London or Tokyo than in Moscow? In each case, the common theme is the amount of energy available; in nature, energy may be measured in joules, while in economies it may be measured in wealth. We may note similarly that the variety of weapons in the respective arsenals of the US and the UK favours the US; not only does the US possess more weapons, but a greater variety of weapons.

It is tempting to deduce that variety is somehow generated or "pumped" by energy, although we might have to be a little free in our interpretation of energy according to situation.

Energy, source of variety

It has long been established that species evolve to be efficient users of energy (Lotka, 1922). If two species compete for the same resource then, during times of shortage, the more efficient will survive. On the other hand, during times of plenty, when speciation occurs — as it does naturally owing to genetic inheritance from two parents — variety may be supported by the environment to propagate and evolve further. Subsequent reduction in available energy may see new species sufficiently changed to be able to shelter in new niches.

It is tempting to equate these ideas to recession and the rise of a variety of businesses during times of plenty, only to see many of them — but not all — go to the wall when times are harder.

Both the natural and the business worlds behave, in this respect, in a way which is consistent with observation of living on the "edge of chaos". To an observer standing somehow detached from the activity, species/businesses generate and multiply, then fall back again, filling the constantly-changing ecological/economic "space" in a seemingly haphazard manner. From this perspective, variety seems to come and go in a complex, continually-shifting pattern.

Variety

Addressing complexity as a subject allows that variety, connectedness and disorder may be treated as commodities, and this is so far outside of our usual experience that it can appear strange at first. For example, the concepts of "not enough", or "too much" variety are not easily grasped. In following topics, we will explore the following variations on variety:

- Minimum variety
- Useful variety
- Limited variety
- Excess variety

Minimum variety

The western world, with its many mouths to feed, has developed agriculture based on large scale mono-cultures. Western farmers grow vast fields of a single species of wheat, or farm salmon spawned in great quantities, or grow a single species of apple. Singular varieties are known to be susceptible to disease, or predation, and a complementary industry exists to provide artificial fertilizers, pesticides and a supply of new, disease-resistant varieties.

Genetic engineering is coming to the aid of farmers who are finding that nature is rather good at generating diseases and predators to damage or feed off their mono-crops.

The genetic engineers hope to keep ahead of the game by conferring disease resistance, say, from one species to another. The approach is necessary to support the enormous population, but it is also energy intensive.

> “Low variety is energy-pumping for high variety threats, keeping an adequate variety is spending the minimal energy at having an adequate variety but increasing the variety is extremely costly in terms of time and efforts.”

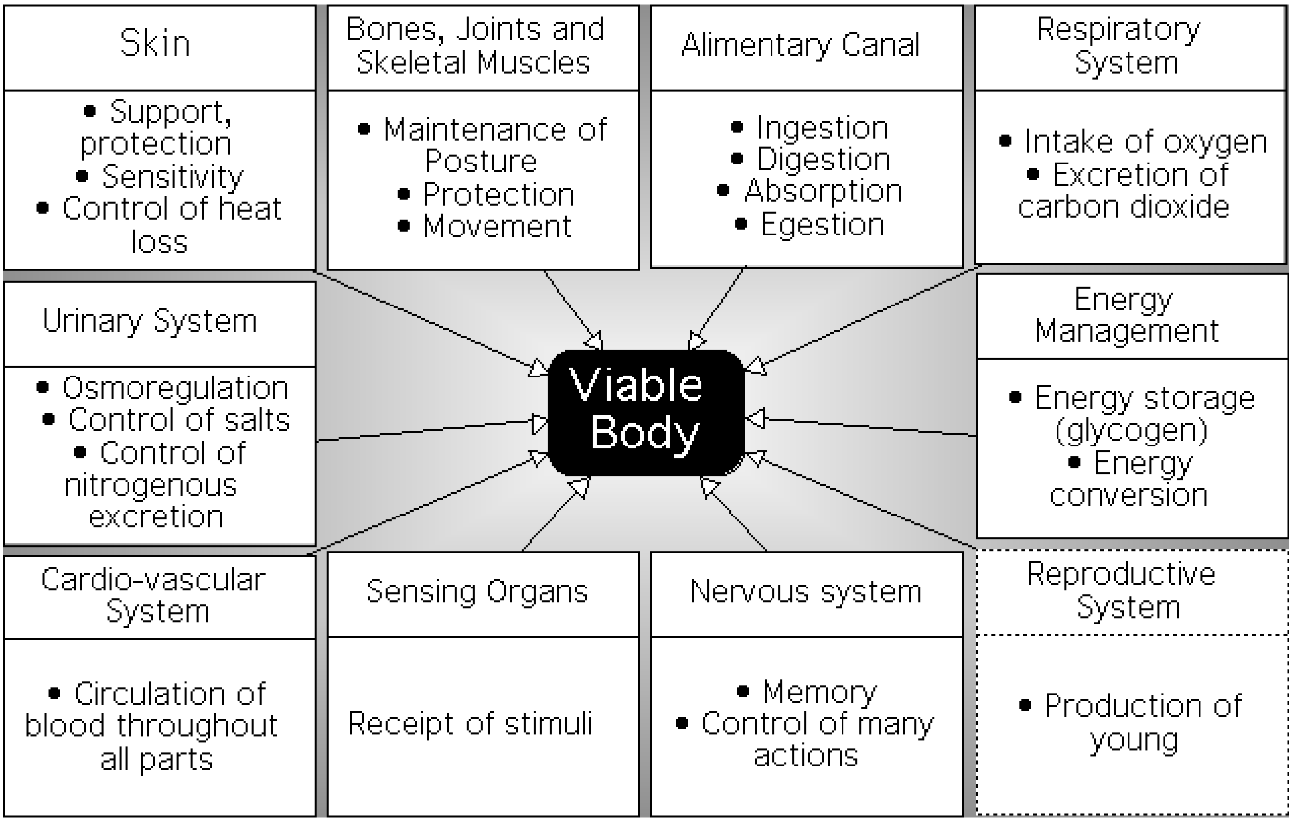


Figure 2: Some component systems of the human/mammalian body. With the exception, perhaps, of the reproductive system, none of the component systems could be removed and leave a viable body.

South American farmers have farmed using poly-cultures for many hundreds of years: poly-cultures bring together complementary plant varieties — mutual nitrogen fixation, natural pesticides/herbicides, wind-brakes, climbing frames, etc. The different plants, working as a set, combat a wide range of threats/potential deficiencies. In the western world, these techniques are well known to domestic gardeners, too, with marigolds and cabbages (for instance) being planted together, since the marigold protects against some cabbage pests. Poly-cultures require much less energy in the form of artificial aids. Their disadvantage, of course, is the unsuitability for mechanisation which militates against large scale cultivation.

Poly-culture farmers probably identified suitable combinations of plant variety by trial and error in the first instance, which raises an interesting question — how much variety is enough?

Clearly there could be inappropriate variety, but can there be too little, or too much, as well?

As figure 2 shows, the various systems within our bodies are complementary, or mutually supportive. With the exception of the reproductive system, little could be removed without serious and immediate death. Even the reproductive system would not be removable if the term "viable" were taken to include self-reproducing. (Non-essentials such as appendix and gall bladder have been excluded; for most adults, they are not essentials for viability.)

As figure 3 shows, the viability of any system is determined, not only by the internal complementary parts, but also the threats which it has to meet. The greater the environmental diversity or threat, the greater the minimum variety essential to viability.

This idea suggests that there may be a potential mathematical basis for determining minimum variety, based on cause and effect.

Useful variety

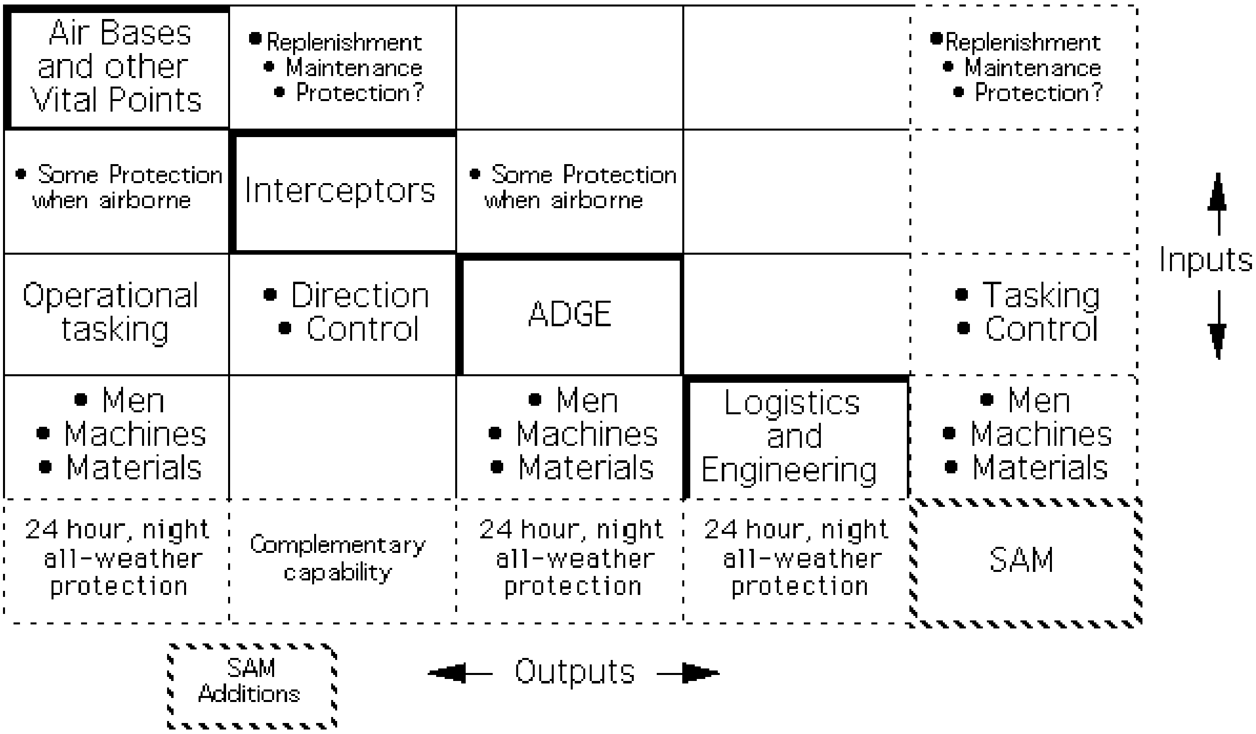
The concept of useful variety is distinct from that of minimum variety. Useful variety makes essential, complementary contribution. For example, the variety of clothes and sizes in clothes shops makes a useful contribution to the ability of the shop to satisfy its varied customers. Beyond the smallest and largest likely clothing sizes, variety would not be useful. Alternatively, consider a word processor or drawing program with varied capabilities for varied people, tasks and environments. Beyond some limit, more variety in the capabilities of the program is superfluous, and could make the program difficult to understand and to use.

Determining the sensible limit of usefulness may not be straightforward. In the clothing shop example, it might be possible to analyse the likely population and to stock only sizes that would sell, although the existence of outsize, short and tall specialist shops testifies to the difficulties of meeting this goal. On the other hand, the ideal variety of capabilities in a word processing package depend upon the tasks it will need to face after purchase, and these may not be so easily predicted.

Or, how about the skills that a company should retain during recession to enable rapid start-up once the recession lifts? Holding redundant skills against a future need is tantamount to predicting the future which, in the event, may not be knowable.

Useful variety, then, is less amenable than minimum variety to mathematical determination, since it implies prediction. Nevertheless, we often choose in everyday practice to hold on to something, or to buy a product with variety which we may not need directly, as a hedge against the uncertain.

> “Useful variety is part of risk management.”



Air Bases and other Vital Points	• Replenishment • Maintenance • Protection?			• Replenishment • Maintenance • Protection?
• Some Protection when airborne	Interceptors	• Some Protection when airborne		
Operational tasking	• Direction • Control	ADGE		• Tasking • Control
• Men • Machines • Materials		• Men • Machines • Materials	Logistics and Engineering	• Men • Machines • Materials
24 hour, night all-weather protection	Complementary capability	24 hour, night all-weather protection	24 hour, night all-weather protection	SAM

Figure 3: An N-squared chart showing a typical air defence organization. In an N-squared chart, component systems are shown on the leading diagonal, with the other rectangles representing interfaces/relationships/inter-flows between the systems. So, Interceptors give "some protection when airborne" to both the Air Defence Ground Environment (ADGE, or ground radar and command network) and to the Air Bases and other Vital Points. The bottom right rectangle, representing Surface to Air Missiles, is cross-hatched to show that it is needed only if the airborne threat to the other members is significant. Were a tactical ballistic missile to be considered a threat, then an anti-missile missile would be needed in addition to SAM.

The minimum system variety to ensure viability is partly determined by the external threats to the system.

Limited variety

Limits to variety can be both perceived and real; first, perceptions. If one asks how many great religions there are, the answer seems to come out at "rather less than a dozen". Judea-Christianity, Islam, Confucianism, Buddhism… before long we start to struggle. If we consider, say, Christianity alone and ask the same question, Catholicism, Orthodoxy (Russian and Greek) and Protestantism emerge… and we start to falter again. Keeping going, if we look at the Protestant sects, we find Methodists, Baptists, Calvinists, Lutherans, and so on...

Again, we soon start to run out...

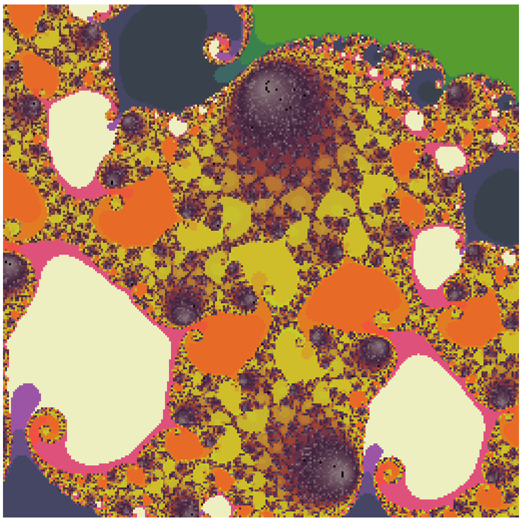
The phenomenon is not confined to religions. How about ethnic groups? Negro, Mongolian, Semitic, Caucasian, Aborigine, Indian… we soon slow down. If we take any one, it can be broken down into a relatively few divisions. As we increase the resolution, we seem to see the same broad constraint on variety emerging, no matter what the general topic.

Why should there be a limit? Why is it so small?

Psychologists and anthropologists propose that there is some in-built, simian inheritance in our brains which tends to make us confused when we try to contain more than about seven mental categories at the same time. (See Miller, 1956.) Experiments with dots randomly scattered on a sheet of paper, and shown for only half a second or so, suggest that perception of numbers of dots up to about seven is simple for most people.

Beyond seven, there is a sharp cut-off, with most people responding with "lots of dots".

Could it be that our reaction to things or situations as being complex is nothing more nor less than an inherited mental processing limit? Perhaps during our evolution, it was unnecessary to address more than seven or eight categories of anything at the same time in a life-threatening situation; perhaps we evolved an ability to perceive up to seven things in parallel under "fight or flight" conditions. If "Miller’s seven" (as the phenomenon is called) is simply that, a subjective and inherited limit of human parallel processing, then perhaps complexity itself is simply our mental processor balking when we try to process too much variety at once…



There are real limits to variety also; these will be explored in a later topic, and are concerned with the relationship between the energy entering an open system, and the resultant speciation.

Connectivity

> “Ah, but a man's reach should exceed his grasp, or what's a heaven for?”
> — Robert Browning 1812-1889

About connections

Open systems can be viewed usefully from a functional viewpoint as receiving inflows (of substance, energy/power and/or information) transforming those inflows into different outflows and passing them on to other open systems.

> “In the process,
> open systems absorb sustenance from whatever passes through them.”

Humans are open systems, and we operate in just this manner. So too do organizations, social groups and processing plants.

From this system viewpoint, connections appear as enabling, supporting or directing flow between open systems, much as veins and arteries enable the flow of life-giving blood.

> “Bundles of connections can be grouped to reduce perceived complexity.”

Bundles of links can be viewed as systems, too, but there is a distinct difference: connection bundles do not materially transform whatever flows through them.

See connection strategies later.

This differentiation into transforming and non-transforming systems is useful in reducing perceived complexity. We can also identify types of connection; these may be two-way (duplex), or one-way (simplex). Telephone lines carry speech in both directions, and are duplex. Power cables support uni-directional current flow and are simplex. The distinction between simplex and duplex is useful. One-way connections permit asymmetry, introduce notion of reachability...

Reachability

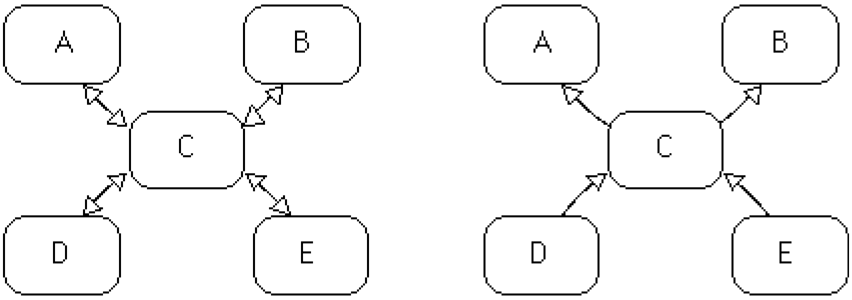


Figure 4: Reachability. Five entities, A to E can be connected using either duplex (two-way) links at left, or simplex (one-way) links at right. The right hand structure is asymmetric, D and E cannot reach each other, neither can A and B.

As Figure 4 shows, duplex connections favour symmetric relations, while simplex connections favour asymmetric relationships. In the figure, reachability is an issue.

For example, is A reachable from B? In the left hand picture, A would be reachable from B if, and only if, C enabled the connection. C would be described as transitive. If C were transitive in the right hand diagram of Figure 4, D could reach A and B through C, but could not reach E (because of the simplex link from E to C); D and E could not be reached at all, and A and B could not reach anything. If C were transitive in the left hand diagram, there would be complete reachability.

Transitivity

Figure 5 shows the impact that transitivity can have on perceived complexity. At the left, all connections are shown between boxes, presumed non-transitive. At the right, simply by assuming transitive boxes and suppressing redundant lines, the perceived complexity is greatly reduced. A physical realization of the two figures might find the boxes in the left diagram having a number of different communication links to other boxes, while at right each box above the lowest pair provides a through-communication service.

Note that the real complexity is still as at left — nothing has changed logically.

Figures 4 and 5 are typical of the representations we employ to convey ideas. Figure 4 might represent some system or organization. Figure 5 might be a "tree" of objectives which contribute to each other via the arrows. (For a practical example of such a tree, see Figure 29.)

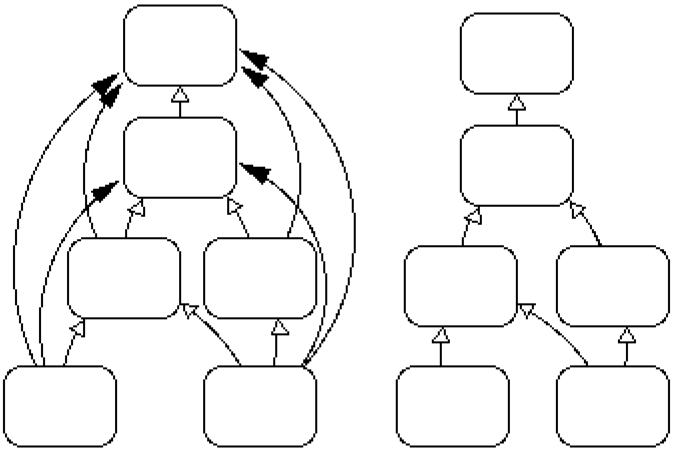


Figure 5: Transitivity. In the left hand tree diagram, boxes are assumed non-transitive, and all simplex connections are shown. In the right hand diagram, all boxes are transitive and redundant connections are suppressed.

Complex behaviour

Observance of chaotic behaviour in the real world has shown that it can develop from the simplest of (seemingly) well-behaved parts. Complex behaviour demands very little variety, but it does require, inter alia, connection between parts and non-linear behaviour of those parts.

It seems that strength of connection can affect behaviour.

Consider just three bodies (e.g. quarks, suns, etc.); their interaction pattern should be simple enough to predict; after all, they must obey the laws of physics. As Figure 6 illustrates, three elementary interacting bodies may behave in an orderly, chaotic or unstable manner according to the strength of coupling between them. At left is the simple view of three interacting bodies.

Interactions between the bodies is two-way, to a strength determined by the "amounts of stuff" in each of the connected systems; and coupling between them. Conditions are identical for all three systems in the model. The graph, at right, is the result of a computer simulation of the systems, and shows the "stuff" an any one of them. In the graph, only the coupling is changed, in the middle.

The left hand section of the graph, low coupling, is well behaved, although the non-sinusoidal shape of the wave might suggest some non-linearity.

The right hand section of the graph, high coupling, behaves erratically.

Physical realization of the conditions used to model the three-body problem are not hard to visualize. For example, the gravitational attraction between two bodies is given by the well-known relationship:

$$F = \frac{Gm_1m_2}{d^2}$$

- F = force
- G = universal gravitational constant
- m_1 = mass of body 1
- m_2 = mass of body 2
- d = distance between the two bodies

For three bodies, the mathematics is similar, giving results similar to those in the graph.

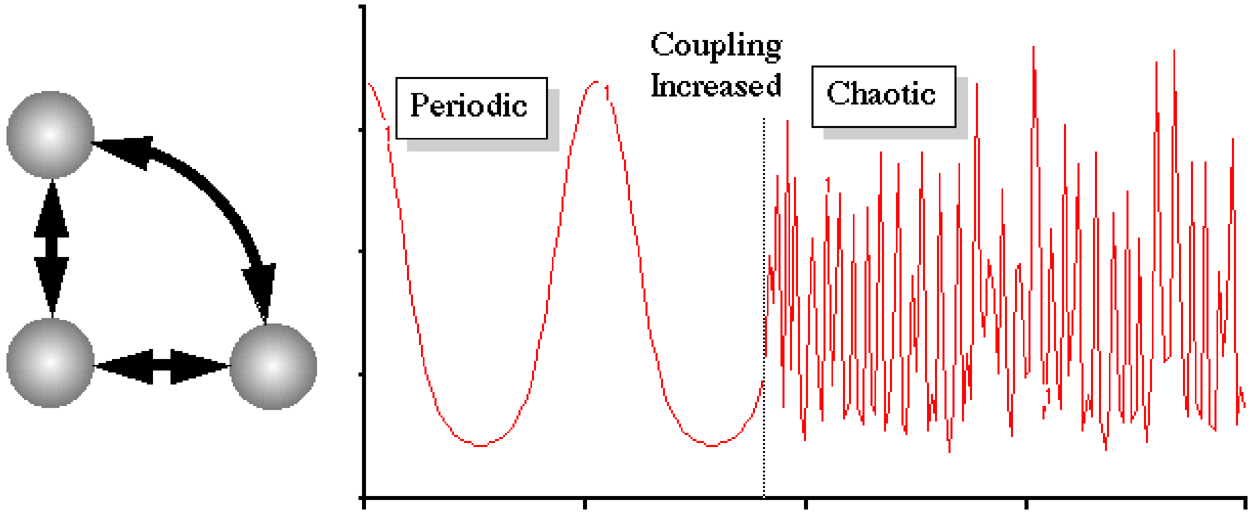


Figure 6: Three body behaviour. Three bodies move under mutual attraction, at left. According to the degree of their mutual inter-coupling, their behaviour may be periodic or chaotic, at right.

If three simple hard bodies can behave in this fashion, how might three complex soft bodies (people) behave?

If such complex behaviour can result when three simple interacting bodies are closely coupled, what might the be complexity of behaviour for three soft bodies, (e.g. humans, interacting ecologies, etc.). Would their interaction pattern be more, or less, complex?

Bounded, stable chaos

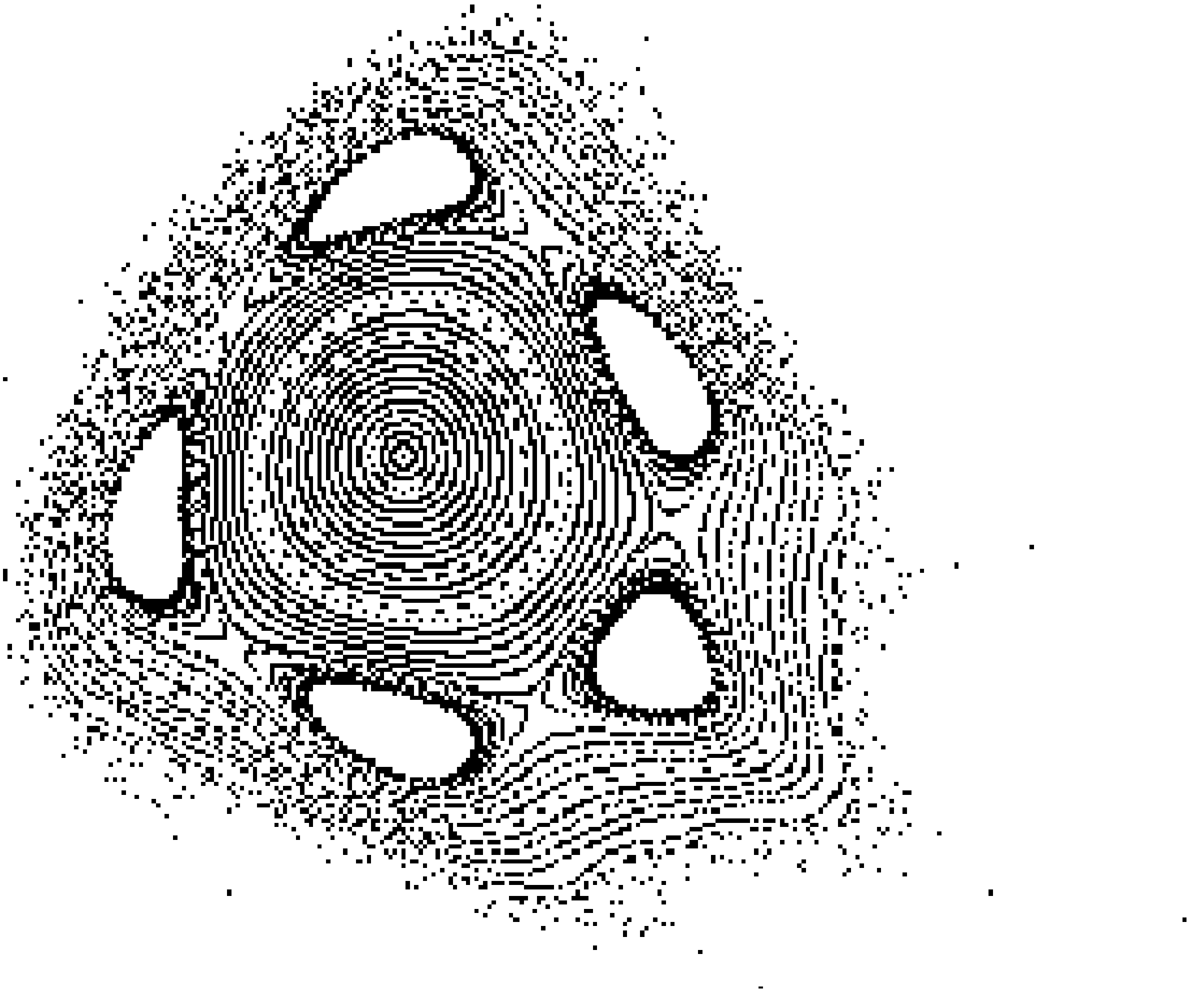


Figure 7: Hénon chaos. The pattern shows the interaction of simple differential equations as a coupling factor between them is increased.

Chaotic behaviour may be complex, but it is not random. In Figure 7 there is a map of Hénon Chaos. The map is built up from simple, non-linear equations. As a coupling factor is increased, the pattern starts from the centre and moves out, producing, initially, concentric "circles"; for each increase, there follows a greater radius. Each "circle" is built up from individual dots, which develop the locus in an orderly fashion.

As the coupling factor increases further, behaviour changes, until the five ovoid shapes emerge, within which there are no dots. No matter what the coupling factor, no dots can appear in those ovoids. Still further increases seem to revert to a more concentric pattern until the equations finally go unstable — witness the dots at the edge of the picture frame.

Connection strategies

Figure 3 presented an N-squared (N2) chart, which is useful in simplifying the complexity of connections. For example, an N2 chart has N x N squares, N of these are on the leading diagonal where they represent the parts of the system, leaving N2 minus N squares to represent all possible interfaces. So, we can do some simple sums: -

Maximum number of simplex links between N entities = N2 - N

If N = 5, then the maximum number of links = 20,

If N = 20, then the maximum number of links = 380

In quadrupling the number of entities (from 5 to 20) the maximum number of links rises (from 20 to 380, or) nineteen times. This is close to, but slightly greater than, a square law.

As the parts in systems become more numerous, the potential for interconnection rises rapidly. Systems with many connections may spend much of their time and effort on receiving inflows and sending outflows. In other words, it is possible for an entity to become "over-connected."

> “Over-connected entities spend more energy processing interchanges than transforming inflows to outflows.”

Observing the world around us, there seem to be some four archetypal strategies for addressing this issue of over-connectedness:

- Specialized interconnector-systems. Some systems become specialized connectors e.g. railways, telecommunications, nerve cells. In essence, they cease to transform inflows to outflows, acting instead as transporters. Railways transport people without materially changing their state. Telecommunications and nerve cells transport data without materially altering the message they represent.
- Interconnection strategies to avoid full connection. Some systems employ strategies which result in connection via convenient, but indirect routings. Telephone connections between individuals in different cities cannot be direct — there are simply too few wires. Instead, telephone calls are passed through exchanges where, using a number of strategies, many calls may be sent down a single connector between exchanges, subsequently being separated out for onward connection. The strategies include time,

frequency and code multiplexing, all designed to overcome the capacity-limits of discrete connectors.

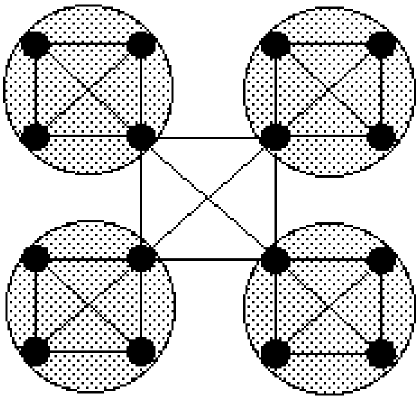
- Stay in small sets. The problem of over-connectedness does not arise if entities stay in small sets. We humans socialize in small sets, as any cocktail party will suggest. As more people arrive, they progressively break into relatively small groups so that the individuals can converse with relatively few friends at a time. Individuals may then migrate between groups from time to time, which can lead to the next point.
- Stochastic/chaotic connections. Sometimes entities need to communicate across a broad front, but cannot afford the overhead of continuous, full connectivity to all potential communicants.

  They may then adopt a strategy of full communication but for only part of the time. This strategy may be organized or disorganized.

  Managers at work would prefer, sometimes, that it were organized and hold meetings accordingly. However, the unpredictability of business requires discussion and decision-making "on-the-fly", and connection patterns between managers and workers may become chaotic. In this context, the term chaotic need not be pejorative; chaotic interaction may be necessary for successful overall system operation.

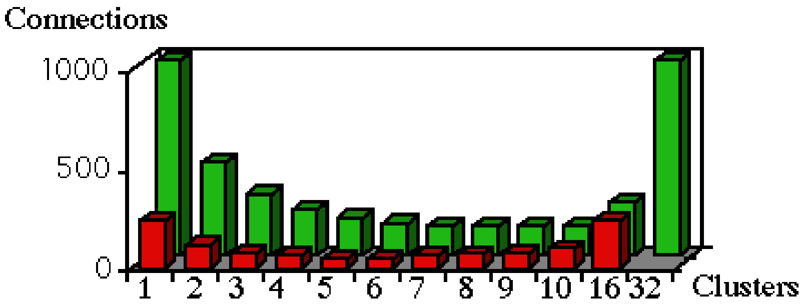
Connection symmetry and simplicity

Figure 8 represents a not-untypical connection strategy amongst entities — the "nearest neighbour" strategy connects each entity to its nearest neighbours only. The strategy is not remarkable, but the consequent number of links presents interesting features according to whether or not the entities are grouped symmetrically, as follows:



- 16 entities in a single cluster, fully connected = 240 connections
- 16 entities in 2 clusters of 8 employs 114 connections
- 16 entities in 2 clusters of 6 and 2 clusters of 2 employs 76 connections
- 16 entities in 8 clusters of 2 employs 72 connections
- 16 entities in 4 clusters of 4 employs 60 connections

Figure 8: Sixteen entities arranged into four groups of four in a flat connection structure (i.e. two-dimensional). Diagram can also be interpreted as a simple hierarchy with the single central figure omitted. The diagram represents a "nearest neighbour" connection strategy.



The numbers suggest that there may be a connection infrastructure minimum at the point of symmetrical grouping of the entities.

Figure 9: The chart shows the number of connections needed to join a given number of entities, according to the number of clusters into which the entities are grouped. The front set of columns corresponds to Figure 8, with sixteen entities. The rear set of columns corresponds to 32 entities. Note that the minimum is sharper as the number of entities increases. Note, too, the discontinuous X-axis

Figure 9 employs the same connection strategy as Figure 8. Note that minima sharpness, i.e. potential infrastructure reduction increases with the number of entities to be dealt with. For many inter-connection schemes, there is a grouping strategy which minimizes infra-structure.

Natural systems may evolve towards such minima where there is survival advantage, e.g. less energy absorbed in the interaction. This potential survival advantage may explain some natural symmetry such as, for instance, the tendency of migrating birds to fly in extended V-formation.

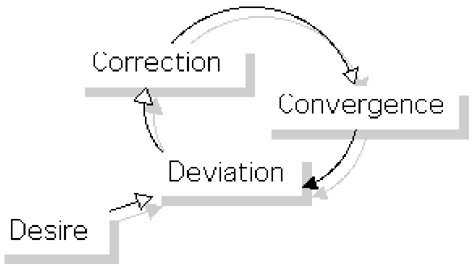
> “It is believed that this formation reduces the energy expended by the flock overall.”

Cocktail parties seem to evolve into similarly sized groups to reduce overall hubbub, enable easier discussion in group. At the start of a party, a single group forms, but splits as further guests arrive. The reasons for the split may be several: circle becomes too large for conversation across the diameter; larger circle exceeds Miller’s seven; too many cross-conversations are possible, and their mutual interference causes the group to fragment; etc. In any event, it is noteworthy that as more guests arrive, groups form and reform until the room may become filled with many similarly-sized groups, all talking at each other. Members within a group will close up to hear others speak above the general hubbub.

Systematically, the overall party self-organizes into symmetrical groups, so reducing the total number of simultaneous person-to-person interactions, and hence the overall noise — or, alternatively, increasing the number of simultaneous, successful conversations. At its height, a cocktail party can seem so complex that it appears to be total chaos — but perhaps this is just our perception.

For many inter-connection schemes, there is a grouping strategy which minimizes infrastructure. Organization designers generally ignore such factors, however; we tend to see the trees, rather than the wood. Looking at the cocktail party, it is easier to see one or two groups, less simple to see the whole party as one system.

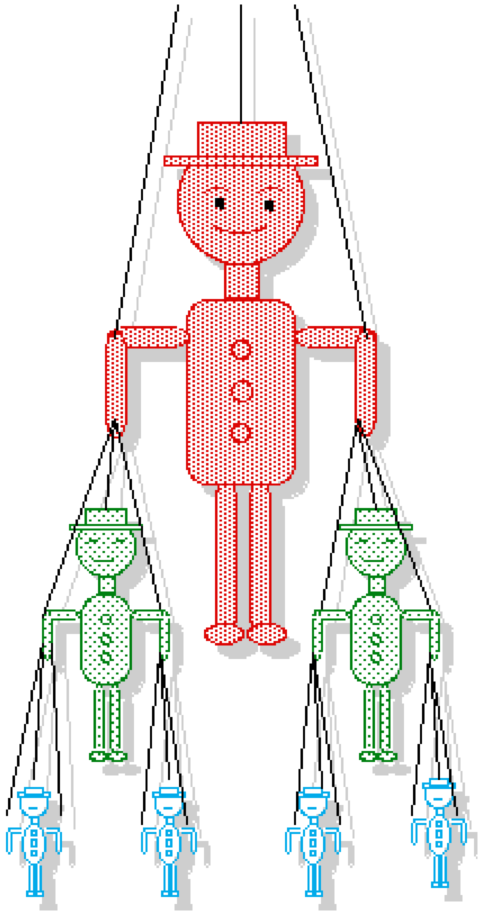
Connections and control



Within both management and engineering, connections between and within systems are used to enable control. Figure 10 shows the scheme from a management viewpoint. A manager has a desire to change or regulate something. They perceive some divergence between that which is, and that which they wish.

The difference is used to generate a correction instruction/plan, the plan is implemented and some convergence occurs which reduces the deviation. In control engineering, the scheme is essentially similar, but more precisely regulated in terms of the dynamic response of the item being regulated.

Figure 10: A simple model of management through control.



As the figure illustrates, control is essentially negative feedback, minimizing deviation from some desired target. Control in management seeks co-ordinated response among subordinates to achieve a manager's desire. This simple notion conceals some less obvious issues:

- Control in management seeks co-ordinated response among subordinates to achieve manager's target.
- Control, therefore, tends to encourage the ideas and initiatives of only one person — the manager.
- Control limits subordinates. A manager may have many subordinates, many of whom may know the details and practices of the work in hand rather better than the manager.
- Control inhibits the subordinates by determining what they can and cannot do.

- Control demotivates subordinates, by the process of inhibiting them.

Figure 11: The Puppet Hierarchy

Figure 11 explores the idea of management control further. It is based on observation of a French ventriloquist, who had a dummy which, in its turn, had another dummy. The larger dummy was teaching the smaller dummy to be a ventriloquist...

In the figure, which represents some views of authoritarian management, the upper puppet controls the lowest puppets through the intermediates by pulling appropriate strings. Clearly, this is not simple. For a start, control requires feedback, up the strings, and the top puppet must be able to sense the response from the bottom. Add to that the idea that management "strings" are made from "soggy elastic" leading to connection delays, and allowing for puppet inertia and we may agree that management control is not practicable using this model. So, how does control work?

Control in action

Evidently, control must mean something quite different in practice. Figure 12 shows an alternative view which seems more tenable. A director (someone who directs, rather than a necessarily-senior person) gives a "doer" bare instructions, based on the directors mental model of the situation and the task in hand. The doer interprets these bare instructions and expands them to meet the needs of the occasion, using his or her mental model. The doer’s actions result in some change or event, which may become evident to the director, who thus sees the consequences of the original bare instruction.

Clearly, this is not the same sort of control as the puppet concept. There are several important differences:

- The director’s and doer’s mental models may differ. The director may have dated knowledge of the task to be undertaken by the doer: they may have different objectives
- Feedback may occur some considerable time after the instruction. Should the director re-direct in consequence, the situation could become unstable, with instructions to change arriving with the doer after he or she has already changed.

In many circumstances, however, Figure 12 seems to be a more likely model of management control than Figure 11. Management control contains within it, then, the potential for highly complex behaviour as individual directors issue instructions to a multiplicity of intermediates, who in turn pass on the instructions to the eventual doers. At each stage of this "Kim’s Game" there may be expansions of the bare instructions, mistakes in repetition and interpretations based on non-aligned mental models.

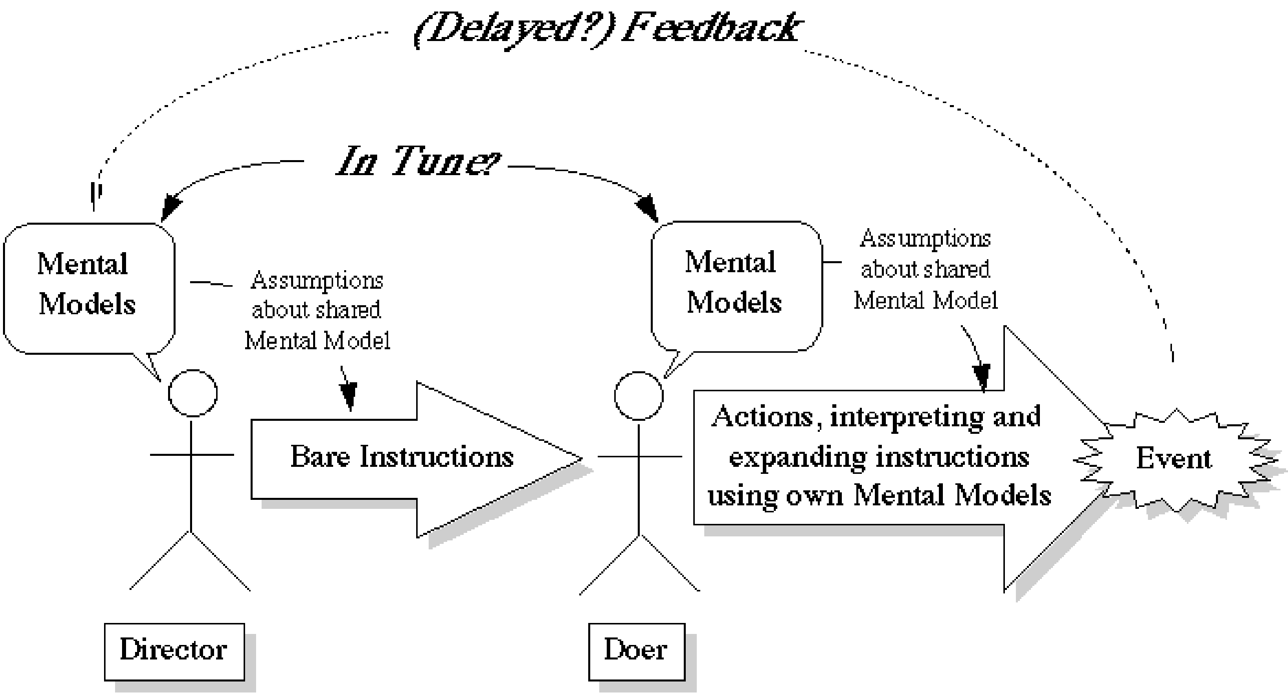

(Delayed?) Feedback
In Tune?
Mental Models
Assumptions about shared Mental Model
Mental Models
Assumptions about shared Mental Model
Bare Instructions
Actions, interpreting and expanding instructions using own Mental Models
Event
Director
Doer

Figure 12: Control in Management

Connections and synergy

The term synergy is used in different ways. In the present context it is defined as: co-ordination and co-operation between parts within a system to produce some desired external effect. Instead of the vertical hierarchy of Figure 11, synergy evokes a flat team structure for management, Figure 13. The figure represents seven meshed teams, six around the periphery and the seventh in the centre. Each peripheral team has a team leader (T) who is a worker, too. The team leaders also operate within a team with a co-ordinator (C) who facilitates interaction between the teams, co-ordinating their mutual interactions.

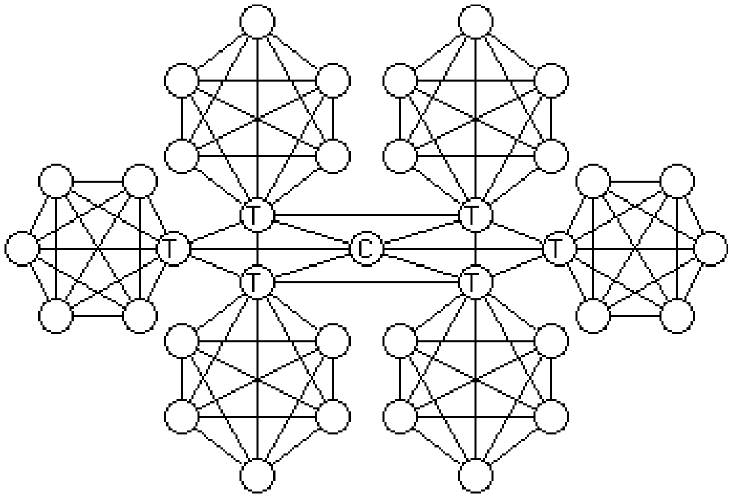


Figure 13: Flat management. T as team leader and C as Co-ordinator.

The figure presents a flat team structure. Unlike the vertical hierarchy, it encourages participation within teams and competition between teams. If it can be made to work, then the result is creative synergy — provided all share same target. How this shared target might come about will be examined below.

Synergy

One view of the mental attitudes of people in an organization is given in Figure 14. At the left, people are seen as having different, uncoordinated viewpoints, represented by map compasses in the absence of an external magnetic field. The arrows point in different directions and, although the individuals may be industrious, the net result may be disappointing.

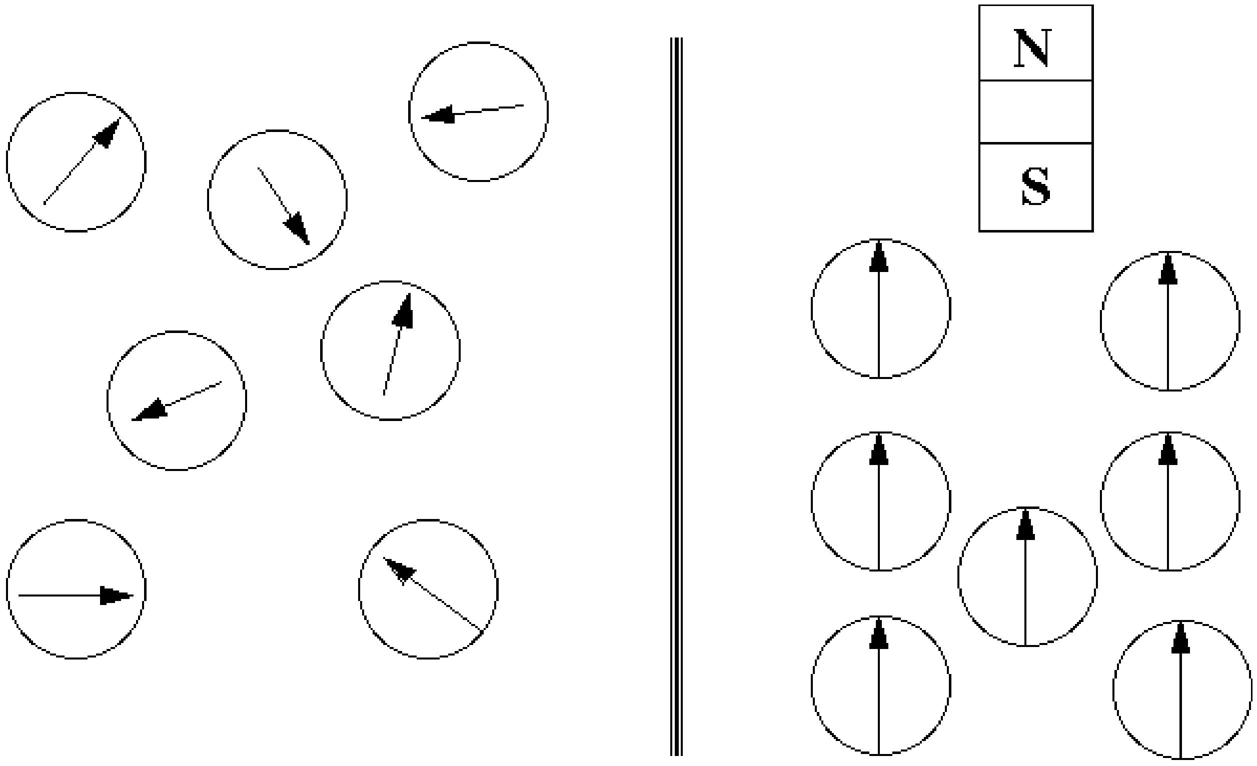
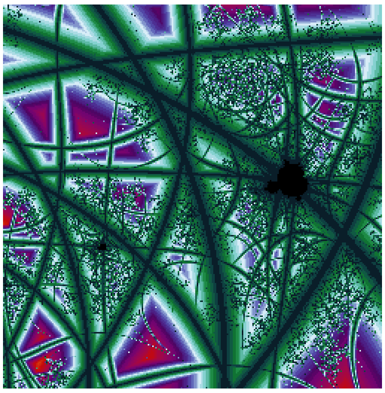


Figure 14: Goals and Synergy

On the right of the figure, the compass needles have become aligned owing to the introduction of a bar magnet which attracts them all in the same direction. In management terms, the attractive influence might be some shared vision to which everyone subscribes. A control viewpoint might invoke discipline as the way to make everyone "point in the same direction".

We might describe vision as "pull" and discipline as "push". In different situations, either or both might be appropriate. In either case, the result is some degree of synergy, reducing the complexity (variety) of group behaviour.

Synergy can emerge in other ways, and is observed in Nature. Trees have been observed to change their growth pattern when other trees are being over-grazed by antelope in Africa. The suggestion is that over-grazed trees emit some chemical messenger which stimulates those down-wind. The mimosa plant is also observed to wilt extensively when touched, although it does not appear to have a nervous system through which instructions, both to wilt and later to recover, might pass.



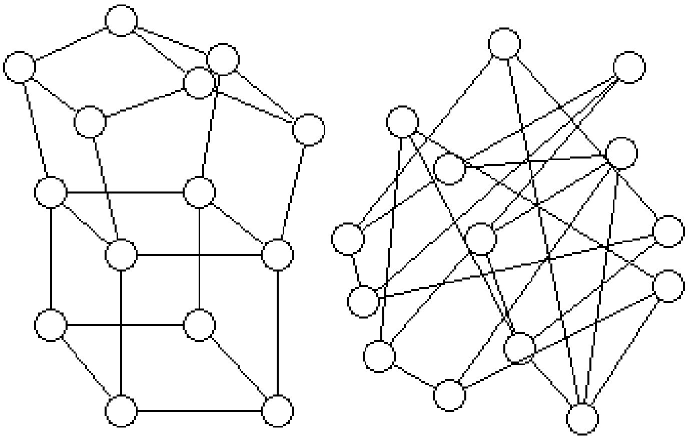
Synergy in the military is often achieved through the use of SOPs — standard operating procedures. SOPs are pre-agreed routines which are invoked either at a pre-determined time or on the occurrence of some event or situation. The key point is that no orders need be given at the time when the SOPs are activated. This obviates any need to communicate which might reveal presence or intent to an enemy.

Fractal 3: Connectivity

Disorder

> “A sweet disorder in the dress, kindles in clothes a wantonness:
> A lawn about the shoulders thrown into a fine distraction.
> A careless shoe-string in whose tie, I see a wild civility:
> To more bewitch me than whenart is too precise in every part.”
> — Delight in Disorder, Robert Herrick, 1591-1674

Entropy, measure of disorder



Variety and connectedness do not fully “capture” complexity. In addition, orderliness is important, too. The concept is illustrated in Figure 15. The diagram at left seems less complex than that at right, although both have same entities, the same connectedness, and the same variety.

Figure 15: The two diagrams have the same numbers of nodes and links, but the figure at right seems more complex, simply because it is more tangled. The overall length of the links in the left-hand diagram is much less. If the nodes are free to move, and if there is some advantage in overall-reduction in link-lengths, then the figure at left may evolve from the figure at right.

Note that the figure at left has, in the course of reducing the overall link-lengths, become much more symmetrical — another way of expressing the reduction in tangling which has taken place.

Configuration entropy

For tangible systems[17], entropy and energy have a defined relationship, albeit a very complex one in many situations, so there is a correspondence or equivalence between an approach based on entropy and one based on energy. Additionally, entropy allows the non-tangible to be considered. There are many definitions and views of entropy, some based on thermodynamics, some on the number of ways in which things can be arranged, i.e. stochastic. They are mathematically equivalent, but particular definitions suit particular purposes.

In general, as is well recognized, entropy measures the degree of disorder in a system. Two types of molecule in a box full of two gases would generally be mixed; if work were done, each molecule type could be moved to different ends of the box. This less disordered, reduced-entropy state is achieved by doing work on the molecules, by expending energy.

Adding cold liquid creamer (rather than dairy cream) to hot coffee in a cup can result in most impressive and bizarre 3-D chaotic mixing patterns before eventually reaching a complete mix. Thermodynamic considerations show that the entropy of the mix is greater than the sum of the separate entropies of creamer and coffee, and common sense will tell us the same — the separate liquids were clearly in a more ordered state before the chaotic mixing. Adding the last piece to a jigsaw puzzle, on the other hand, completes the picture and reduces entropy. In this case, specific inter-relationships between parts are important, and the disorder is less when the jigsaw is intact. One view, then, of entropy is concerned with the way things are organized in relation to each other. This can be called configuration entropy.

Configuration entropy is the degree of disorder in pattern, organization and structure. Zero entropy is exemplified by a perfect crystal at zero degrees Kelvin: there is no movement, no vibration, bonds are regular, ordered and at their lowest net-energy state. Configuration entropy can be used as a measure of all kinds of disorder: heights of people in a queue (are they in height-order?); books on a shelf (are they ordered by colour, size, subject, frequency of use?); fields on a farm (are they equidistant from the farm, rectilinear or shaped, arranged to offer minimum tractor travel?); and so on. If we wish, we can calculate entropy quantitatively; it is concerned with the way things are arranged and with their relationships. However, the notion of configuration entropy may carry us further if we temporarily put aside the urge to calculate, and proceed with the concept qualitatively — knowing always that, in principle, we can calculate should it prove useful.

---

[17] **Tangible symbols** are a type of augmentative and alternative communication (AAC) that uses objects or pictures that share a perceptual relationship with the items they represent as symbols. A tangible symbol's relation to the item it represents is perceptually obvious and concrete — the visual or tactile properties of the symbol resemble the intended item. Tangible Symbols can easily be manipulated and are most strongly associated with the sense of touch. These symbols can be used by individuals who are not able to communicate using speech or other abstract symbol systems, such as sign language. However, for those who have the ability to communicate using speech, learning to use tangible symbols does not hinder further developing acquisition of natural speech and/or language development, and may even facilitate it.

Consider a medieval countryside, perhaps in rural England. Human occupants enter the land, somewhat haphazardly. They associate into, say, three or four villages. The “coming together” into villages represents a reduction in overall disorder, when compared with the previous meanderings. The three villages independently set up organizational structures: they elect leaders and allocate tasks to individuals, they till the land and raise cattle, seeking to create order. Disorder (entropy) seems to be reducing. Now, some of the villagers set out to explore, find the other villages and move home. In the process of leaving their villages and exploring, disorder increases. As they settle into their new homes and, perhaps, bring new organizational ideas and structures to bear, disorder again reduces. Perhaps there is a pattern in open systems, with disorder first increasing and then reducing, to be followed by another increase and then a further reduction.

In the same vein, it is possible to consider systems as, by their nature, reductions in entropy — at least within the boundary of the system. Similarly, connections between systems, bringing order and structure, must reduce configuration entropy, although entropy may well have increased during the creation of the links. At a fundamental level, it seems likely that the common thread binding all systems ideas together is the desire to perceive order, to reduce entropy either in fact, or in perception. Kast and Rosenzweig (1972) observe that open systems tend towards greater differentiation and states of higher order (reduced entropy). We see energy promoting entropy and systems forming to reduce it — hence, perhaps, the continual variation in entropy.

For our purposes, since we are dealing with complex patterns, configuration entropy is the most suitable idea:

$S = k \ln W$
where:—
S is entropy
k is Boltzmann's Constant
W is the number of ways things can be arranged

Increasing energy increases entropy or disorder.

How might order develop naturally from disorder?

Here appear to be at least two concepts for the spontaneous emergence of order from disorder:

- Since a complex system is made from many interacting parts, it might seem that there are a vast number of ways in which those interactions could occur. However, it is also likely that there are relatively few of this potential combinatorial explosion of possibilities which can self-sustain, i.e. produce a viable whole.

- Some processes within, and interactions between, the parts of a complex set of systems may require less overall (lattice?) energy, conferring survival benefit on particular arrangements.

Following topics explore these alternatives.

Viable pattern development

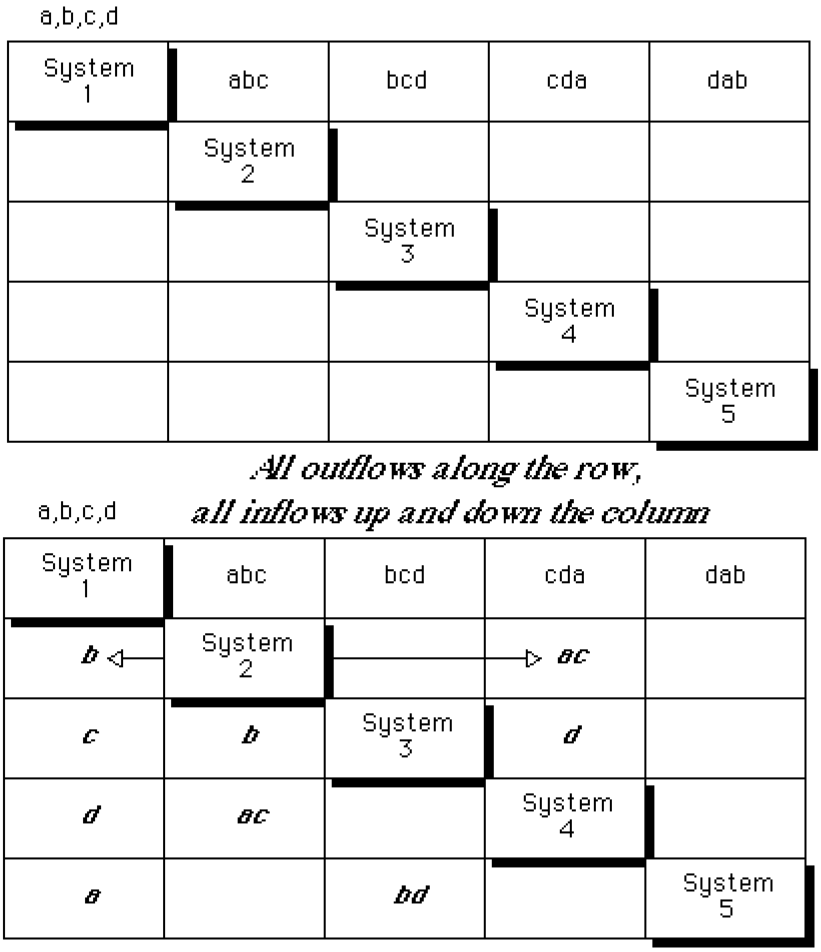


Figure 16: The progressive development of complementary systems to produce a self-sustaining set.

Figure 16, top matrix, shows five systems, initially unconnected, perhaps wandering freely and coming together by chance. They might represent some biological organisms, or perhaps organizations within an economy. System 1 is able to synthesize four discrete varieties, **a**, **b**, **c**, and **d** into four composite varieties. System 1 synthesizes these composite varieties, **abc**, **bcd**, **cda** and **dab** as a continuous process, and creates a local environment rich in the composites.

System 2 is able to decompose variety **abc** into **a** and **bc** as shown in the second matrix. Systems 3, 4 and 5 also decompose their composites as shown. The interchange of varieties between each system is now balanced, with each receiving the varieties it needs, and each providing the varieties needed by the others — so long as the external discrete varieties continue to enter System 1 from outside the set. You may check this by observing that the varieties entering each system (in its column) are the same as the varieties leaving that system (via its row).

The result is stable. Each system has its needs met, and has no need to expend energy in seeking an essential, but missing, input. Indeed, we can treat Systems 1 - 5 as a **single item**, e.g. System X. This is order emerging from disorder. The pattern is also particular — while there are several patterns of decomposition which would satisfy the conditions for the second matrix, many decompositions would not reconcile the column/row rule for variety in/variety out.

The patterns, once formed, also resist change. Figure 17 shows a slightly more complex arrangement of system interactions than those of Figure 16, with four discrete varieties, **a** to **d**

← Outputs →

	1	2	3	4	5
1	A	abc	bcd	abd	abcd
2	a	B	bc		
3	b		C	c	d
4	c	a	d	D	b
5	d	a	b	c	E

↑ Inputs ↓

Figure 17: A synthesis/decomposition set used as a basis for the simulation of Figure 18

The matrix has been simulated to observe its dynamic behaviour, Figure 18. The simulation shows how tolerant of sudden changes in the external environment the set of interacting systems has become. Perturbations are rapidly smoothed out and shared between the five Systems, A - E. This resistance to external perturbation is open systems stability.

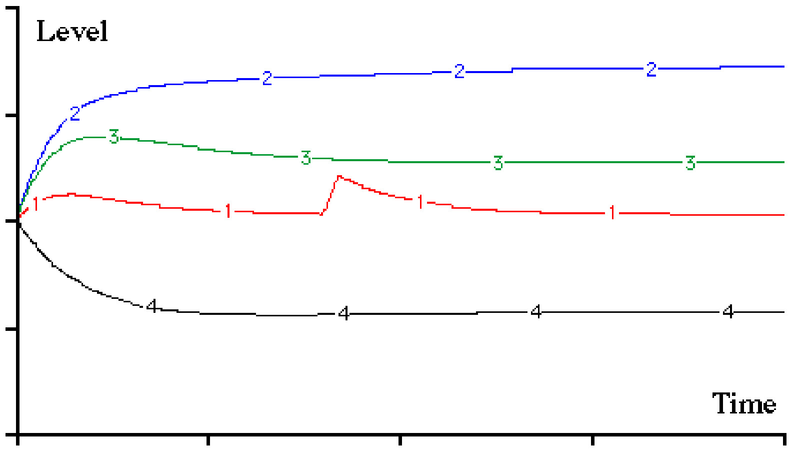
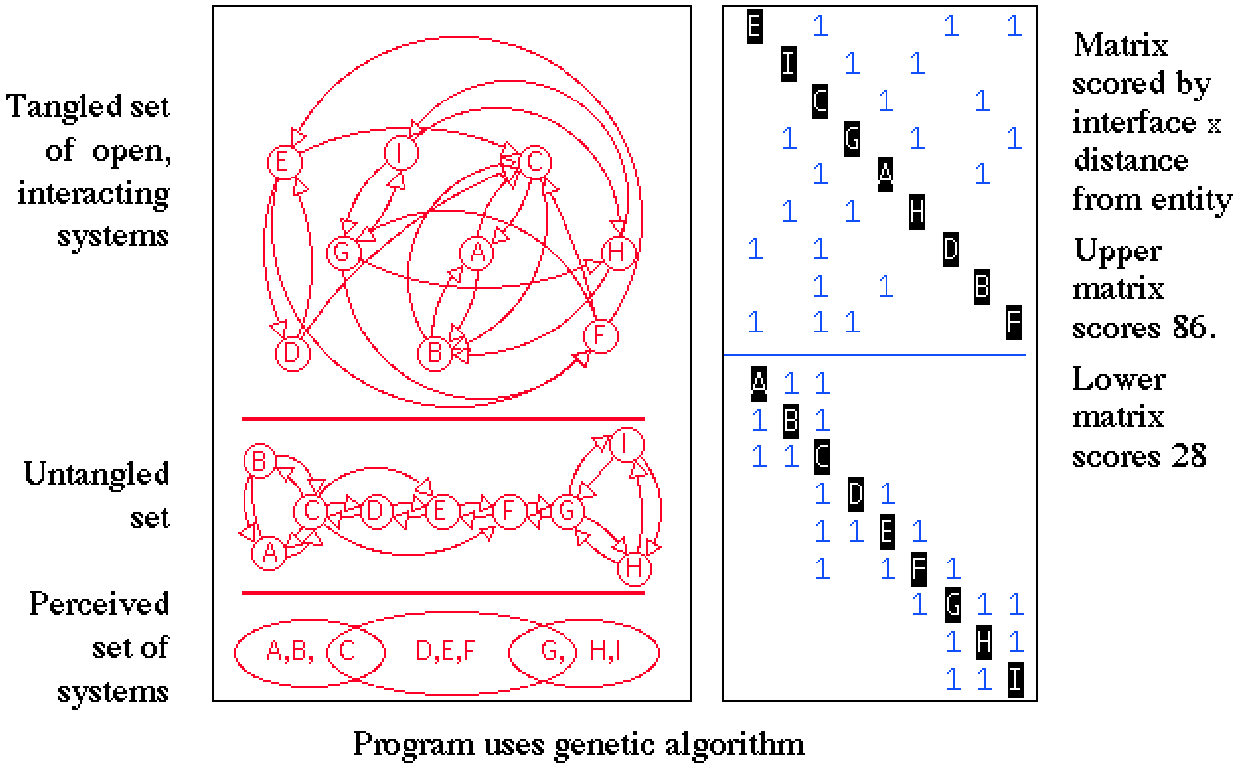


Figure 18: Dynamic simulation of the matrix of Figure 17, showing the levels of the four varieties within one of the systems. A large pulse of variety a (trace 1 on the

graph) is introduced from an external source. Note how its effect is absorbed and distributed amongst the other levels.

Reducing lattice energy

Entropy, or at least a measure which is a useful, practical measure of disorder, underlies the technique at work in figure 19, which is a useful way of developing the structure, organization or architecture of a complex arrangement of things. The things in question might be people at desks in an office, software modules in a processor memory, microbes in a soup, electronic components in a design — almost anything where a system develops disordered, connected variety.


Tangled set of open, interacting systems
Untangled set
Perceived set of systems
E
I
C
G
A
H
D
B
F
A,B,
C
D,E,F
G,
H,I
Matrix scored by interface x distance from entity
Upper matrix scores 86.
Lower matrix scores 28
Program uses genetic algorithm

E		1				1		1
	I		1		1			
		C		1			1	
	1		G		1			1
		1		A			1	
	1		1		H			
1		1				D		
		1		1			B	
1		1	1					F

A	1	1						
1	B	1						
1	1	C						
		1	D	1				
		1	1	E	1			
		1		1	F	1		
					1	G	1	1
						1	H	1
						1	1	I

Figure 19: The figure is read clockwise, starting with the top left diagram. It shows a tangled set of connected entities. These are mapped into the matrix, top right, which is evolved using a genetic algorithm to the more ordered matrix, bottom right. This, in turn, maps into the untangled set, centre left, which can be perceived as a higher level set of systems, bottom left.

The tangled set of interconnected entities in the figure is translated into the matrix, which is scored by the simple expedient of measuring the distance of each of the numbers, representing a connection, from the letters, representing the entities. Using a genetic algorithm — a program that evolves the answer — the lower matrix is evolved, in which all the letters are connected exactly as before, but the re-ordering of rows and columns has reduced the entropy. The pattern of "1s" looks neater and tidier, too. Mapping back into the systems domain results in the untangled set of systems at centre left, which is both visually and mathematically simpler and less complex. Finally, at bottom left, comes perception of order.

Reducing the tangible disorder has enabled us to see higher order systems — this is a perception jump, it reduces disorder in the brain. An example of this process of lattice energy reduction, used in the conception of a complex system, is shown later — see Figure 40.

Feeling the penny drop

When we finally understand a complex situation, we experience a sense of completeness or satisfaction. Do our brains naturally search for reduced entropy? Is this search for reduced entropy behind:

- Right-brain activity.
- Dreaming.
- Déjà vu.
- That essential part of a problem popping into the mind when doing something completely different?

Perhaps the brain evolved as a sophisticated reducer of perceived disorder, hence categorization, stereotyping etc..., might be naturally-evolved means to reduce complexity (and duration) of mental processing. In fight or flight situations, it might be essential to survival to reduce mental disorder.

Consider the following simple problems which suggest how our brains seek states of reduced disorder. In attempting to solve the problems, try to observe yourself at work. You might find the following:

- The sequence of letters can be completed only after the context in which the letters occurs has been identified.
- First, search for context.
- Second, invoke context-specific tacit knowledge.
- Result, feeling of completeness, satisfaction and a subsequent inability to unsee the solution!

1)

_ _T W T F_

2)

H
A
LA_ IER
E

If you find difficulty in solving the first sequence, count how many letters there ought to be — that should provide sufficient context for the answer to appear, but where does it appear from?

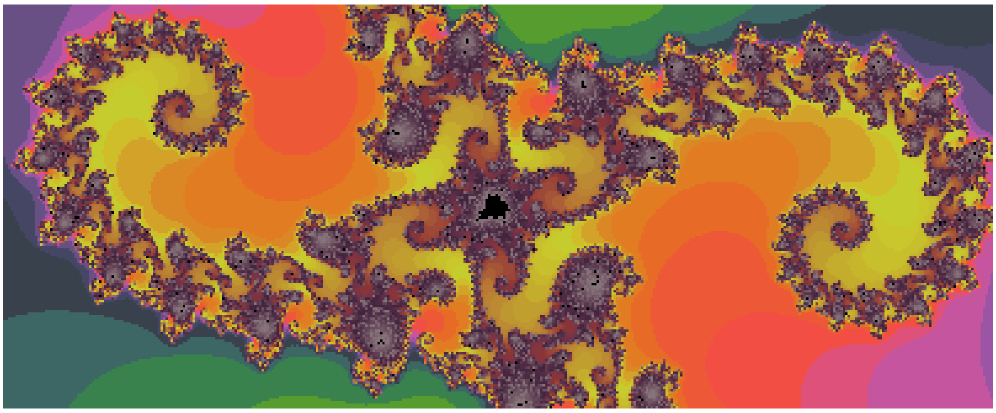
If you have difficulty with the second sequence, did you try to complete the shorter, vertical word first, then see if the horizontal word fitted? Did you employ the strategy of going through the alphabet? Most of all, did you notice that feeling of simple satisfaction when you eventually solved the sequence?

Summary

There seem to be at least two ways in which order may emerge from disorder. Both means of developing order — Complementary systems and Darwinian evolution — occur in nature, but each is quite different. Both means seem equally likely to occur with organizations as with organisms:

- Complementary systems can form rapidly, through chance encounter (or by design). Not restricted to biological forms. Very few of possible configurations actually complement each other — others may not complement, may even be mutually inimical. Group consumption of energy lower than sum of separate set members.
- Darwinian evolution essentially biological, takes a long time, evolved species are most efficient users of available energy.

Perhaps it is not quite as simple as the two bullets suggest, however. Evolved flora and fauna also form complementary sets — prey/predators, food chains, CO2/O2exchanges, etc. The natural world evolves systems which survive by forming into complementary sets, evolving again as their environment changes. Could these two features form the essential basis for the underlying stabilities of economies and social systems?



Fractal 4: Curls

Getting a handle on complexity

Systems thinking

> "Belief is the end, not the beginning, of all understanding."
> — Johan Wolfgang von Goethe, 1749-1832

Models and vantage points

Complexity, as we have seen, can be part real, part perception. To clarify our perception of complexity, we need some strategy which will allow us to cut through the web of complexity and see the essence of whatever it might be that we are addressing. There might be several ways of approaching this goal, and we will address two that seem to be most effective:

- Building models to represent some aspect of a complex whole that interests us.
- Finding vantage points from which to view the complex whole so that we are, in effect, "outside" the situation, taking a detached, third-person view.

To be useful in the context of complexity, models are most likely to represent some aspect of complex, open, interacting systems. Models may be:

- Static models, looking perhaps at groupings, structure and relationship.
- Dynamic models looking at changes, often over time, within and without of the whole in which we are interested.
- Minimalist, if they are not to become as complex as that which they seek to clarify.
- Vantage points are positions from which to view a complex "something". They include:
    - Third-person viewpoints, not unlike the so-called "out-of-body" experiences (OBEs) that some people recount, perhaps after an operation during which they seemed able to look down upon the operation, seeing themselves, the staff, the operating theatre, etc…
    - Time-compressed viewpoints, rather like time-lapse photograph, or using fast-forward on a video cassette recorder, through which it is possible to see patterns of behaviour not visible from our normal perspective.
    - Hierarchy shifts, particularly upward shifts, which allow us to see the behaviour of a system in the context of wider issues.

We will examine these ideas in more detail, since they may hold the key to cutting through complexity.

Models

A model is an abstraction, a simplified representation of a more complex thing:

- Complex models represent many parts, many relationships and much detail. Each component is represented as an approximation only, however, which inescapably means that the whole is many products of many approximations. It is not only difficult to understand such models, but one cannot easily see the flaws which they may contain, nor the implicit assumptions upon which they are inevitably based.
- Simple models, on the other hand, cannot represent the detail that many consider essential. It is certainly the view of many experienced practitioners that a minimalist model cannot represent enough detail to offer substantial results.
- Models of complexity seek to reconcile these different viewpoints by carefully modelling the underlying essence of the problem/ issue/ situation.

As an example, consider the many battle models, computer simulations generally, that are in common use around the world. Typically, they represent two opposing forces, often with one attacking and one defending. By representing the attackers' and defenders' weapons, organizations and tactics as faithfully as possible in the computer, it is hoped to predict the outcome of a potential battle. Such models are used to evaluate different starting points, different tactics, and to persuade purse-string holders that such-and-such a weapon systems is the best buy.

Typically, such models run from some starting condition to an end, with both sides suffering (simulated) casualties. It is in this area that models seem to deviate radically from reality. The models generally fail to represent the changing human condition. In the models:

- Soldiers do not become afraid.
- Each side fights on until one or other runs out of resources, weapons, etc...
- Decisions are infallible, being represented generally by no more than a time delay, rarely (if ever) by mistakes.
- Training has little or no effect.
- Combatants and generals do not learn during the combat — their performance is the same throughout.

- Any belief that combatants might have in the justness (or otherwise) of their cause is irrelevant.

We know these omitted factors to be important, so why are they ignored? For three reasons, it seems:

- To include them would introduce a high degree of complexity into the models, since we would have to represent the dynamic behaviour of human beings.
- We would find it difficult to validate such models against reality.
- Also it is believed that models without human frailties can be valid.

The notion that models of battles between humans need not represent human behaviour may, on reflection, seem utterly bizarre — but is the current paradigm.

To overcome such limitations, and in the process to cut through complexity, it is evident that a different approach to models is needed. Following topics introduce one such approach, and there may be many others. The approach followed below is formed around the concepts associated with the idea of a "system".

A system model

The concept of a system seems to be fairly simple. We all know intuitively, or from everyday experiences, what a system is. Figure 20 shows one simple representation of a system as a collection of parts which operate together to transform inflows to outflows.

We are systems in this context, we convert food to energy, ideas into actions.

Definitions of "system"

We need, sometimes, to be a little more precise about this idea of "system". Here is my definition:

> “A system is a set of organized, interacting parts which, when complete, exhibits properties or capabilities of the set as a whole which are not attributable exclusively to any of the parts.”

This definition is rather deeper than, perhaps, it may seem at first.

It contains the following concepts:

- The notion of sets, that is groups of things which share some common label, purpose or characteristics.

- Organization, that the set members are not simply scattered around, but that they exhibit form and structure. From this notion emerge systematic concepts.

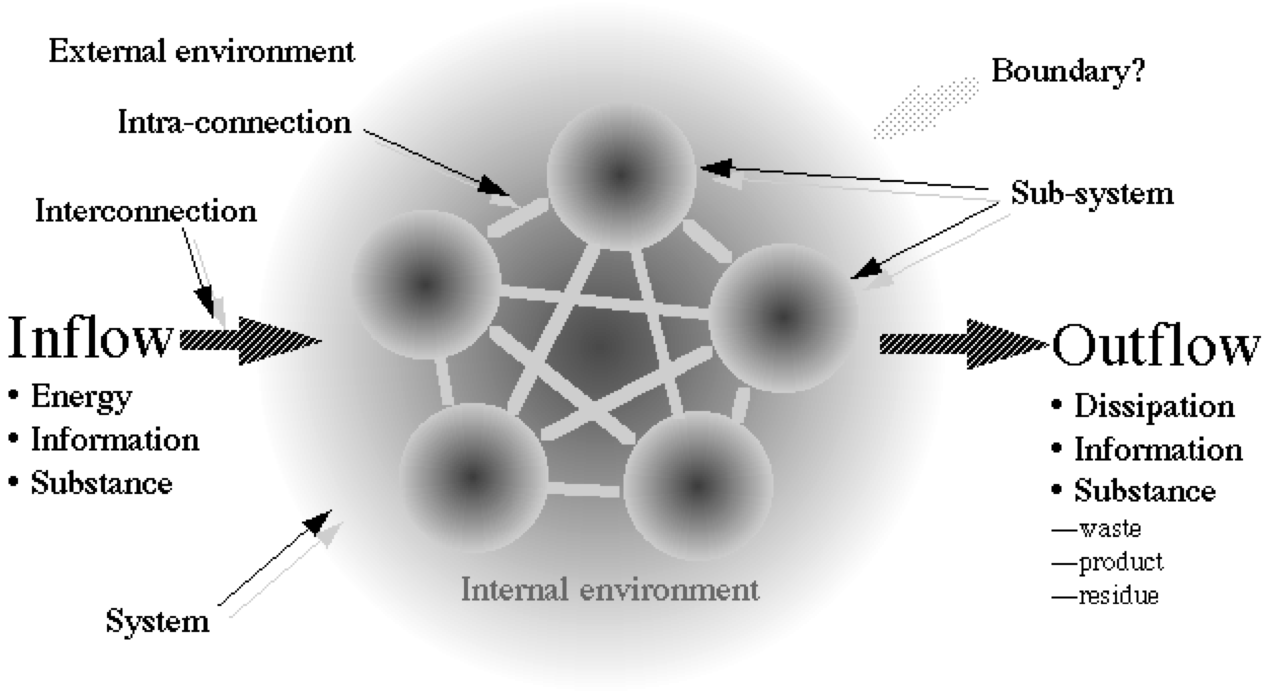


Figure 20: A simple representation of a system comprising internal, interacting parts which, together, transform inflows into outflows. Implicit in the figure are notions of organization, structure, capacity, work, consumption and dissipation.

- The idea of completeness, that the set must be complete for the overall features of the set to emerge.
- Emergent properties, those features of a system which are exhibited by the whole, but which are not attributable exclusively to any part (e.g. self-awareness from the human brain, flight from an aeroplane, picture from a jigsaw).
- The importance of interactions between the parts as contributing to the whole, rather than just the sum of the parts. From this notion emerges systemic concepts.
- The concept of holism, that there are properties of the whole that cannot be reduced.
- The basis for hierarchy, which is perceptible when a set is complete, when that set exhibits emergent properties, and which then allows the parts and their interactions to be considered as an entity at a higher level of perception.

An alternative definition, equally valid but rather more abstract, might be:

> "A set of interacting entities which, with their relationships, together reduce local entropy"

This definition also reveals system concepts, some of them different:

- Sets.
- Interactions.
- Structure and organization, without which entropy will not be reduced.
- Relationships as being on par with entities in terms of importance.
- Localization, that any system's influence is a local phenomenon.
- Metrics, in that entropy can be calculated.

Upwards and outwards — Simple nested systems

Starting with the simple model of a system, it is straightforward to develop a further model showing hierarchy. Figure 21 shows a 3-tier hierarchy with some system-of-interest (SOI) which we wish to consider at the lower right. Within the SOI can be seen intra-connected sub-systems at a lower level of hierarchy. On a level with the SOI are sibling systems which exist and interact with each other and the SOI in an environment. Where all the siblings, including the SOI, form a complete set, then the set can be given a new name, called containing system in the figure. The containing system exists at a higher level of hierarchy than the SOI, and is itself interconnected to other systems, its siblings, at this higher level.

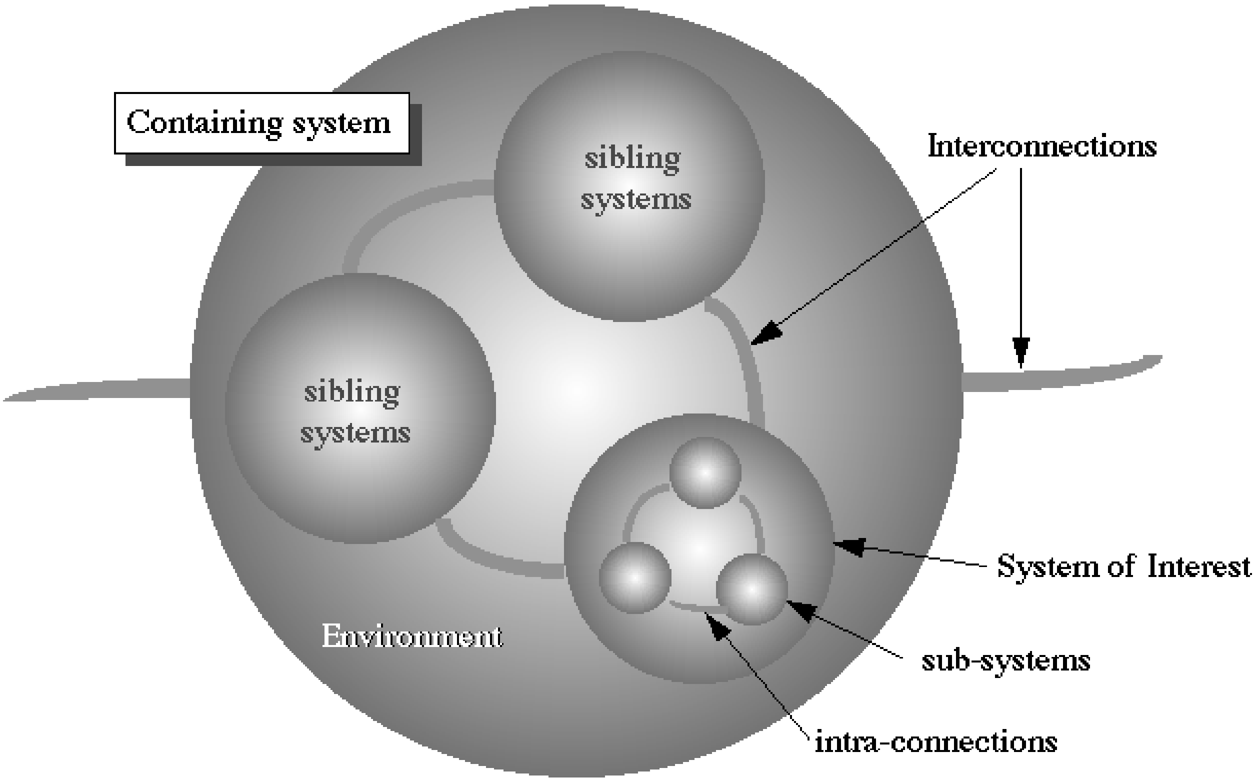
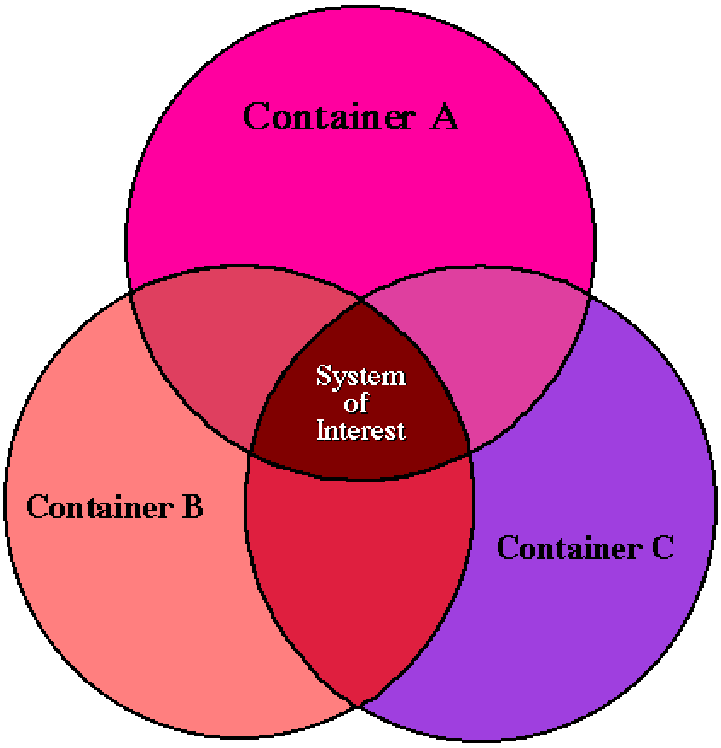


Figure 21: A 3-tier hierarchy of systems showing a system-of-interest interconnected with two siblings inside a containing system. Within the system-of-interest can be seen contained systems, or sub-systems, which are intra-connected.

Simultaneous multiple containment



The two models above are not wrong, but they do paint a potentially over-rosy picture. It is possible for a SOI to exist within more than one container at a time — see Figure 22.

Figure 22: Simultaneous multiple containment. A system of interest can exist within several containers at the same time.

The idea that a system may exist within several containing systems at once becomes obvious with some examples:

- A fighter pilot exists within a flying system, a family system, a squadron system.
- A power unit exists within a radar system, a power distribution system, an interference suppression system.
- A shoe-manufacturer exists within an industry, an environment, a market.

This concept of simultaneous multiple containment reveals potential combinatorial explosion of inter-relationships, and exemplifies one of the cardinal differences between soft and hard approaches to understanding systems and their behaviour. Hard viewpoints seek to simplify hierarchical arrangements into simple vertical arrangements. Human ancestry, in this mode of thinking, would be traced back in time through fathers (or mothers in a matriarchal society). A softer approach might recognize that the genes of the offspring derive from both parents, and will trace the source of genes along all ancestral paths. The soft approach is both more complex and more comprehensive.

Simultaneous multiple containment can be managed in many circumstances by identifying the objectives of each container and showing how the SOI contributes, with its respective siblings in the appropriate Container, to those objectives. So, the fighter pilot contributes to:

- The goals of (e.g.) the air defence system of which he is part.
- The nurture and support of the family, nuclear and wider, of which he is part.
- The morale and esprit-de-corps of the squadron of which he is part.

Notice that there may be interaction between these containing system objectives. A pilot may find himself behaving less boldly when he has a wife and children to think about.

Ideas of closure and completeness

Another approach to handling complexity is causal loop modelling (CLM). CLM, as the name implies, models in loops of cause and effect. There are very few things where actions are not accompanied by reactions, by feedback of some kind. Push, and you will feel some resistance. Pull, and you will feel some inertia. Soak up ink, and the blotting paper will gorge, reducing the soak-rate. Tell someone to "get a move on" and see the resentment. Introduce a new law and see all the efforts to find a way around it.

CLMs get to the heart of complex issues. The search for direct cause and effect results in minimalist models, and transcends particular disciplines, so that a group of people with quite different backgrounds and viewpoints can come together and agree on the "way things work" via the medium of a CLM.

CLMs are easy to develop. Consider population. Population is increased by births, decreased by deaths. More than that, the rates of births and deaths also increases with the size of the population. This is represented in figure 23.

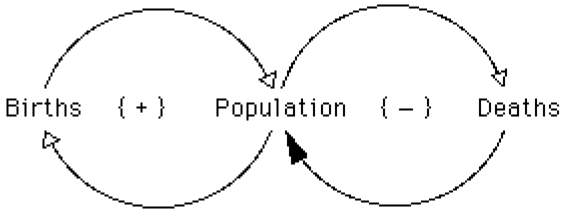


Figure 23: Causal loop model of population dynamics. The solid-headed arrow indicates an inverse relationship, i.e. as the number/rate of deaths rises, the population falls.

Figures 24 and 25 extend the simple model of Figure 23.

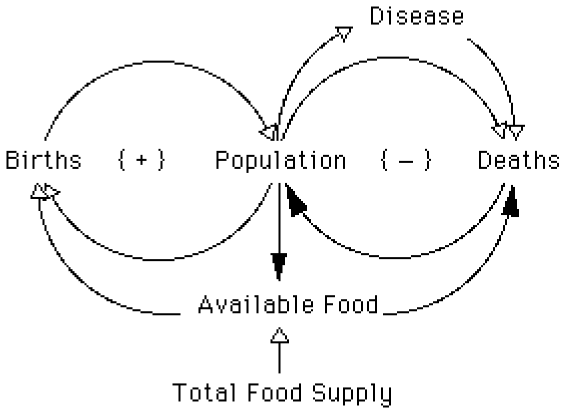


Figure 24: Developing the CLM of Figure 23. Disease is added as a special cause of death, the model implying that the greater the population, the greater death due to disease. Food is also shown, as increasing births and reducing deaths.

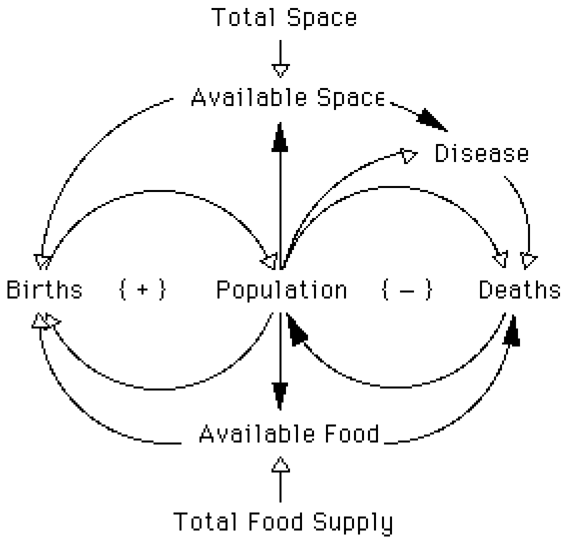
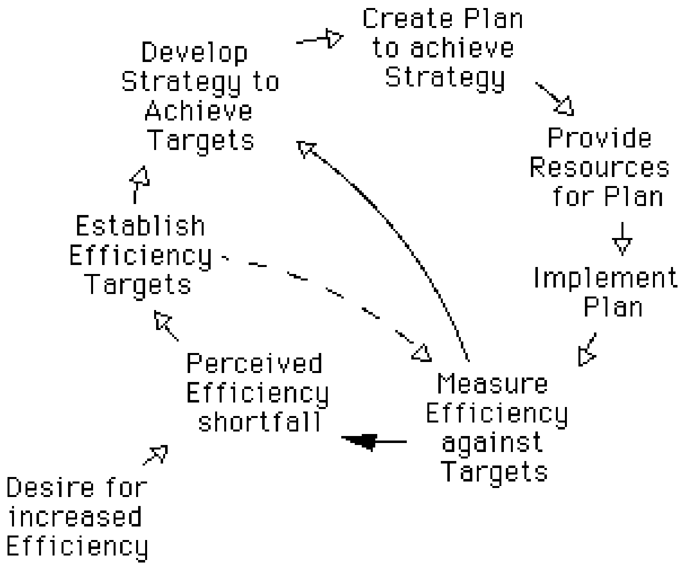


Figure 25: Extending the previous CLMs further by adding available space. The more space, the more spread out the population, and hence the less the occurrence of stress-related and infectious diseases. The more space, the greater the number of births, simply owing to opportunity and the basic fecundity of the population. Note, there has been no definition of population type. Human? Reptiles? Rabbit? Crocodile?

CLMs and Completeness


Create Plan to achieve Strategy
Develop Strategy to Achieve Targets
Provide Resources for Plan
Establish Efficiency Targets
Implement Plan
Perceived Efficiency shortfall
Measure Efficiency against Targets
Desire for increased Efficiency

CLMs are valuable to establish completeness, especially in a set of ideas. Consider the possible causes of inefficiency in a business. Scratching the head might come up with:

- Too much waste.
- Excessive rework.

Following the causal loop model approach might result in Figure 26.

Figure 26: A CLM for improving business efficiency.

Figure 26 is best read from the bottom left, desire for increased efficiency: this desire enables the perception of a shortfall in efficiency. This perception must result in the establishment of some arbitrary level of efficiency, which might well include some minimization of rework and waste, to accommodate the original "head scratchings". To be achieved, targets require some strategy, followed by a plan, followed by resources to implement the plan. Once the plan is in operation, efficiency may be measured against the targets, and there will be either an improvement or there may need to be a rethink and a different strategy.

In order to complete the CLM of Figure 26, to return to perceived efficiency shortfall, it was necessary to introduce ideas not on our original list. In other words, closing the loop encourages us to complete our set of ideas. We could now produce a much better list for causes of inefficiency:

- Lack of established efficiency targets.
- No strategic plan to improve efficiency.
- No measurement of efficiency against targets.
- No management of efficiency improvement.
- Not forgetting:
    - Too much waste.
    - Excessive rework.

In producing the list from the CLM, we have established a simple, but satisfying, approach to a complex issue which, somehow, does not seem to be quite so vague and complex any more.

Positives from negatives

Figure 26 and the efficiency example shows one other, sometimes seemingly-miraculous, phenomenon. We humans are especially good at suggesting the possible causes of some malaise or deficiency. For example, most people find it much easier to state the likely causes of poor morale than of high or good morale, or the basis for ineffectiveness than for effectiveness. It seems to be some deep-rooted psychological feature that we find it easier to see the down-side, the negative aspects. The efficiency example, and CLMs in general, can make use of this feature, as follows:

- Collect all the possible causes of deficiency, defectiveness, down-side, etc...
- Dropping the pejorative terms, form a CLM from the remaining statements.

The resulting CLM will present some idealized system. So, we may turn our predilection for looking at the down side to advantage. Consider truancy from school. Possible causes might include:

- Lack of parental discipline.

- Lack of school supervision.
- Dull, uninteresting lessons.
- Lack of lessons aimed at particular student needs.
- Glamorous perception of "bunking-off", or truancy, in the eyes of some students.

Such a list is relatively easy to produce and, particularly with the help of truant students and professional teachers, to extend. The list is full of pejorative terms: "lack of", "dull, uninteresting". Consider now figure 27. The model contains the elements of the bulleted list above with pejorative terms dropped, and the various items have been formed into a set of loops, each loop containing a closed set of ideas for reducing truancy, the sets combining to create an "idealized" model of truancy management.

One loop proposes closer co-ordination between parents and the school. Schools in the UK operate in loco parentis, in the rôle of parent, once the children are in the school, but it has to be up to the parent to ensure the child arrives at school in the first instance. The loop from "school supervision" to "control of students" shows the school’s responsibility. Both of these loops are about control, but control is a negative concept. Yes, it may be possible to make students attend school, but the very act of making them attend may destroy their interest in learning.

The main loop shows the school addressing the main issue — making school relevant, interesting and "the place to be" for students.

This kind of ideal model shows that partial solutions to issues are unlikely to work. So often we see successive governments attempting to resolve complex issues by addressing only one facet, by treating the symptoms rather than the cause. Not only are such efforts doomed to disappointment — they are generally counter-productive in the long run.

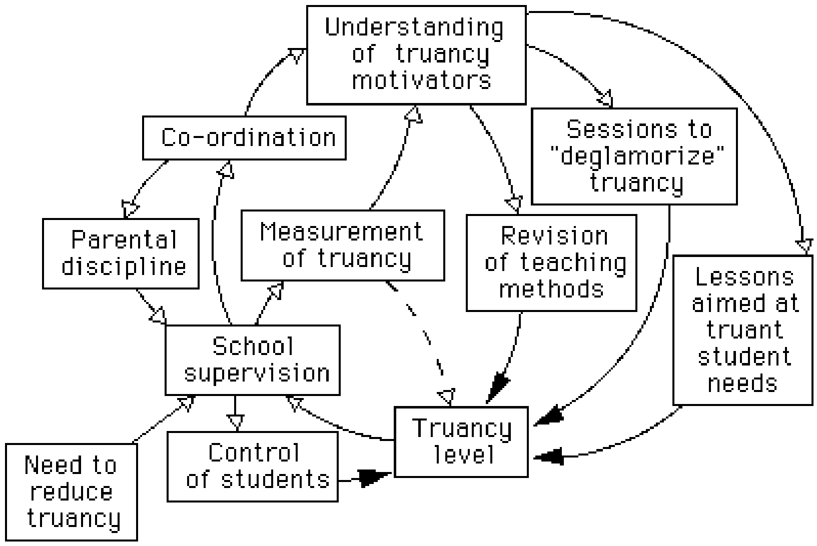

Understanding of truancy motivators
Co-ordination
Sessions to "deglamorize" truancy
Parental discipline
Measurement of truancy
Revision of teaching methods
Lessons aimed at truant student needs
School supervision
Truancy level
Need to reduce truancy
Control of students

Figure 27 also shows the futility of trying to weight the complementary approaches to something like truancy. All the approaches are needed — it is not sensible to pick and choose.

Figure 27: An idealized model of truancy control. Filled-in arrow heads indicate an inverse relationship between the elements connected by such arrows, i.e. if the element at the arrow-tail increases, then the element at the arrow-head will fall, and vice versa.

Pairwise comparison to reveal hidden structure

Sometimes there are so many factors in some issue that we find it difficult to see the wood for the trees. One way to get a handle on such complex problems is to employ pairwise comparison. As with CLMs, this technique makes use of our psychological make-up. We find it difficult to organize, say, ten things into a prioritized list, and asking five people to produce the list together would cause all sorts of difficulties. On the other hand, we generally have much less difficulty in prioritizing between only two things. It is usually easy to say that A is better than B, or that A comes before B, or that A is more important than B. If we can take a list of many factors and compare them two at a time, it is possible to integrate all the comparisons into a network. An example will reveal all!

What are the attributes of some proposed new airliner? Suppose they are:

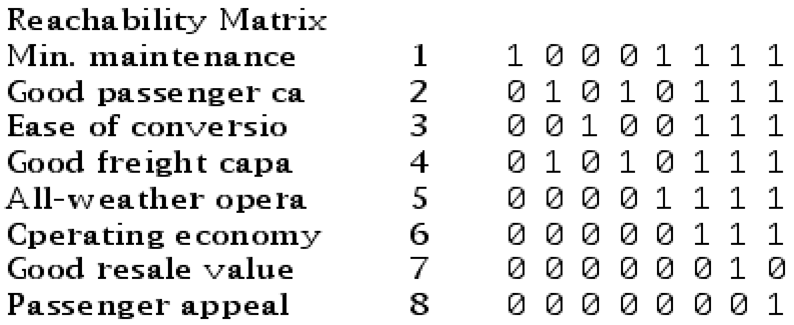
- Good freight capacity.
- Ease of conversion — freight to passenger.
- Good passenger capacity.
- Minimal maintenance cost.
- All weather operation.
- Good short-haul economy.
- Passenger appeal.
- Operating economy.
- Good resale value.

By asking the questions:

> "Does attribute A strongly contribute to attribute B, or is it the other way around, or to they mutually reinforce, or is there no relation?"

It is possible to create a matrix of relationships (Figure 28) from which a tree of relationships may be formed.

The attribute enhancement tree at figure 29 can be drawn directly from figure 28 using notions of reachability and transitivity illustrated in figure 5 shows that all of the attributes of the airliner are connected through the concept of operating economy, which enhances customer appeal provided it results in lower fares, and will contribute to the eventual resale value. (Note that the tree employs the concepts of reachability and transitivity — see Figures 4 and 5.)



```
Reachability Matrix
Min. maintenance        1     1 0 0 0 1 1 1 1
Good passenger ca       2     0 1 0 1 0 1 1 1
Ease of conversio       3     0 0 1 0 0 1 1 1
Good freight capa       4     0 1 0 1 0 1 1 1
All-weather opera       5     0 0 0 0 1 1 1 1
Cperating economy       6     0 0 0 0 0 1 1 1
Good resale value       7     0 0 0 0 0 0 1 0
Passenger appeal        8     0 0 0 0 0 0 0 1
```

Figure 28: Matrix of Contributions — printout from author's ©CADRAT computer tool. N.B. some of the titles have been truncated by the program.

Figure 29 represents a simple case, and the answer might have been reached easily by trial and error. Using the pairwise comparison technique enables large numbers of factors to be mutually-related, in situations where trial-and-error methods would be out of the question.

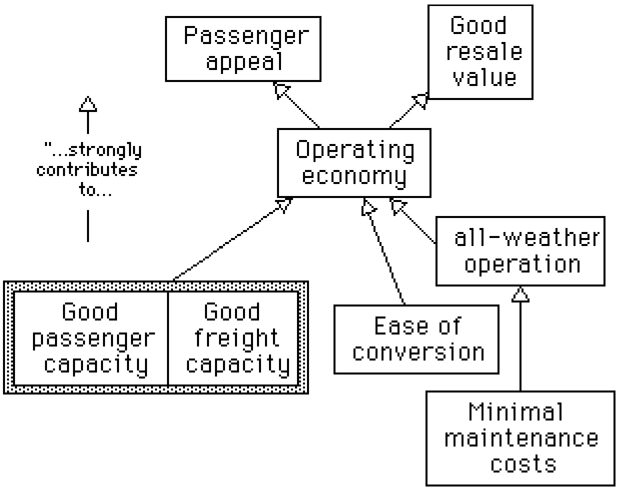


Figure 29: Attribute Enhancement Structure, drawn from pairwise comparisons in figure 28.

Developing a standard approach

> "To have conscientiously studied the liberal arts
> Refines behaviour and does not allow it to be savage."
> — Ovid, 43 BC-AD 17

With all the potential for complexity, and all the variety we see about us, it would be valuable to have a standardized way of approaching complex issues and situations. The models in previous chapters are leading towards that goal by allowing us to view the world from a rather simple perspective. In many ways, much of the complexity about us can be reduced by organizing our perceptions into a hierarchy of systems, with complexity of detail being masked by viewing from a higher perspective — by standing back, and viewing from a distance.

It may not be quite that simple, of course. If we observe carefully how people approach the creation of new concepts, or tackle some complex issue, a pattern of behaviour emerges:

- First there is a process of disordering, of increasing entropy in order to encompass a richer variety. In everyday terms, issues seem to become more complex when we scratch below the surface, and we soon find ourselves embroiled in a wealth of detail.
- Second, there is a process of connecting up, or linking, the profusion of varieties to establish their relationships.
- Third, once the varieties have been linked in some way, they may be grouped into sets or clusters, so reducing either real or perceived entropy, or both.

This three stage process up and down the hierarchy/entropy tree occurs in many walks of life. It is as though, to reach a better state, we have to disorder the current state, throw all the cards in the air, and then rearrange them into a new, hopefully-better state.

Given simplifying systems models and a standard, three-step process, might it be possible to approach complex issues in a straightforward manner? For this to be true, it is necessary that:

- Many different situations can be seen from similar perspectives.
- We find some standard systems model to accompany the 3-stage process.

One such model is the generic reference model (GRM), which describes any system, and which has three parts, form, function and behaviour. Why the three parts?

- Some systems have only form, e.g. the solar system for which it may be difficult to ascribe purpose without resort to (arguable) transcendental causes.
- Some systems have form and function, e.g. human heart, which is both highly organized and which clearly has the purpose of pumping blood around the tissues of the body.
- Some systems have form, function and behaviour, e.g. a management group which has structure/organization, which fulfils a rôle, and which undoubtedly exhibits behaviour if only because no two management groups perform identically.

So, although the GRM purports to address any system, the user of the GRM is required to select the appropriate parts of the model to suit the context. Moreover, the GRM looks at the insides of a system only. For instance, a GRM view of a human would see skeleton, organs, central nervous system, senses, response to stimulus, etc..., but would not reveal external appearance.

The generic reference model

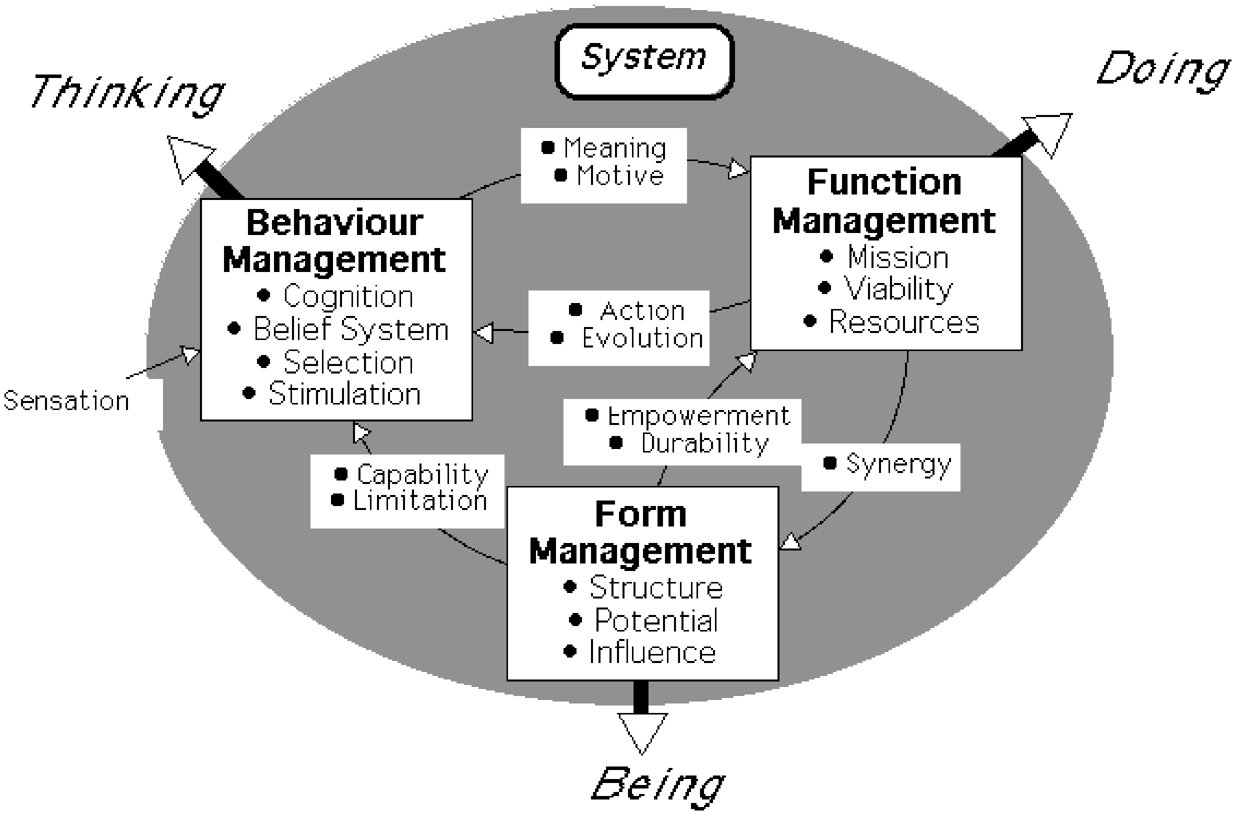


Figure 30: The generic reference model.

The generic reference model is shown at its highest level in Figure 30. It represents those parts of a system which correspond to being or existing, doing or functions, and thinking or behavioural response. The GRM does not explain why a system exists, functions or behaves, but shows what features must rationally exist for properties and capabilities to arise. For example, the model does not predict particular behaviour; instead it indicates what features must be present in any system which can respond adaptively to different stimuli, i.e. those features which go towards the management of behaviour. Having said that, the model is based on extensive research into a variety of systems to find those features which are common to them all.

Generic reference (function) model

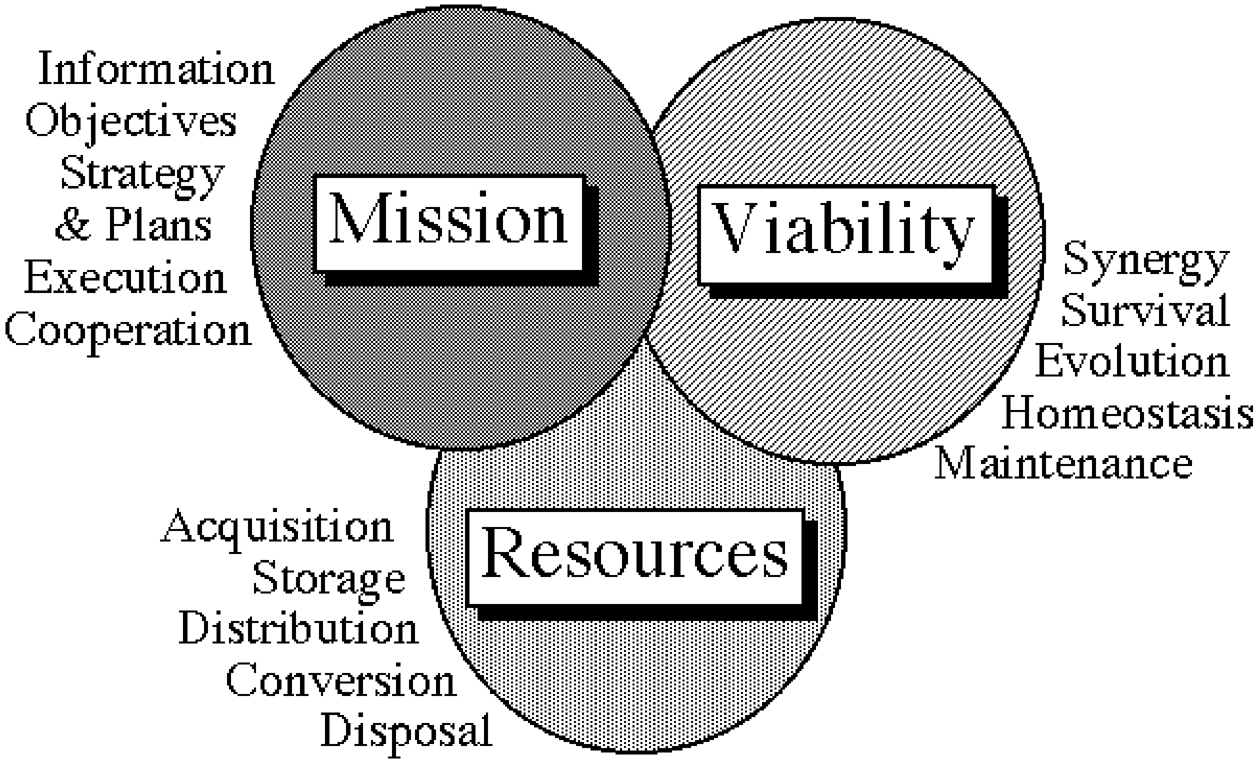
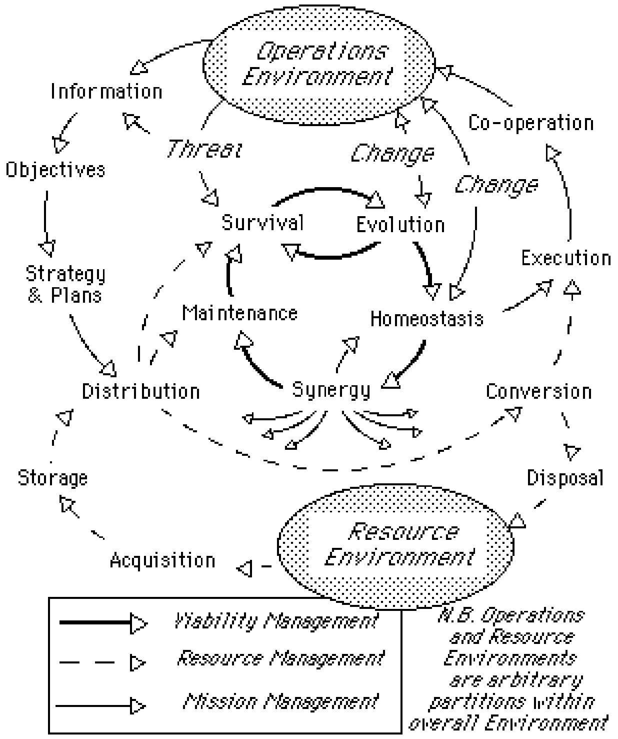


Figure 31: The generic reference (Function) model.

Figure 31. shows one version of the generic reference (Function) model (GR(F)M). The model shows the three subdivisions interacting with each other as follows:



Mission management

In principle, in the management of a mission (an undertaking to achieve some goal) can be organized under the following headings:

- **Information management:** the collection, organization, storage manipulation and presentation of information.
- **Setting objectives:** based (in part) on the information.
- **Formulating strategies and plans:** to achieve the objectives.
- **Executing:** the plans.

- **Co-operating with others** in the environment in the prosecution of the plan.

Figure 32: The generic reference (function) model showing mission management, resource management and viability management features. The system of interest is shown as interacting with two external environments, an operations environment and a resource environment. Note the central nature of viability management, represented by the heavier arrows.

Reproduced by permission of John Wiley and sons.

Viability management

For any system to persist in its pursuit of the mission, it must remain viable.

Viability is founded on five pillars:

- **Synergy:** Co-operation and co-ordination between various parts within a system to produce some external effect.
- **Evolution:** The (slow) adaptation of a system in line with/response to changes in its environment.
- **Survival:** Management of threats, generally by avoiding detection, self-defence or damage tolerance, or some combination of these.
- **Homeostasis:** The regulation within a system to provide the internal parts with a suitable environment.
- **Maintenance:** Detection, location and replacement of non-functioning parts.

Resource management

In principle, the management of resources is encompassed under the following headings:

- **Acquiring** resources needed to maintain viability of the system of interest.
- **Storing** resources until needed, either explicitly or simply by virtue of slow transit.
- **Distributing** resources to the point where they may be employed.
- **Converting** resources from their raw form into some more useful form for maintaining system viability.
- **Disposing** of residue, waste, dissipation or anything not wanted in the system.

These various parts may be considered acting together along the lines shown in Figure 32.

As the figure shows, the various parts of the GR(F)M cannot really be treated individually, since they are mutually interdependent. Nonetheless, it is practicable to identify individual parts of a system first, so long as they are subsequently intra-connected into a whole.

Generic reference (form) model

The generic reference (form) model also arises under three headings, as follows:

Structure

- **Boundary**, or the periphery of the system of interest, through which interactions with other systems must pass. The boundary may be hard or "fuzzy".
- **Sub-systems**, those systems contained within the boundary.
- **Connections** that enable intra-actions between the sub-systems and interconnections with other, external systems.
- **Relationships**, perhaps by location or through some third factor, which falls short of connection, e.g. two parts both contributing to centre of gravity.

Influence

- **Cohesion**, influences within a system which bind the parts together. For stability, these must balance dispersive influences.
- **Dispersion**, influences within a system which encourage the parts to separate.
- **Environment**, that which mediates the cohesive and dispersive influences, i.e. enables the effect of those influences.

Potential

- **Power**, the summation of the various discrete sources of power within a system, giving the rate at which energy might be convertible.
- **Capacity**, the amount of energy and/or stuff which can be stored within the system. With power gives the total energy within the system.
- **Redundancy**, the replication of parts, often to manage failure or damage.

The whole form model may be represented symbolically as in figure 33.

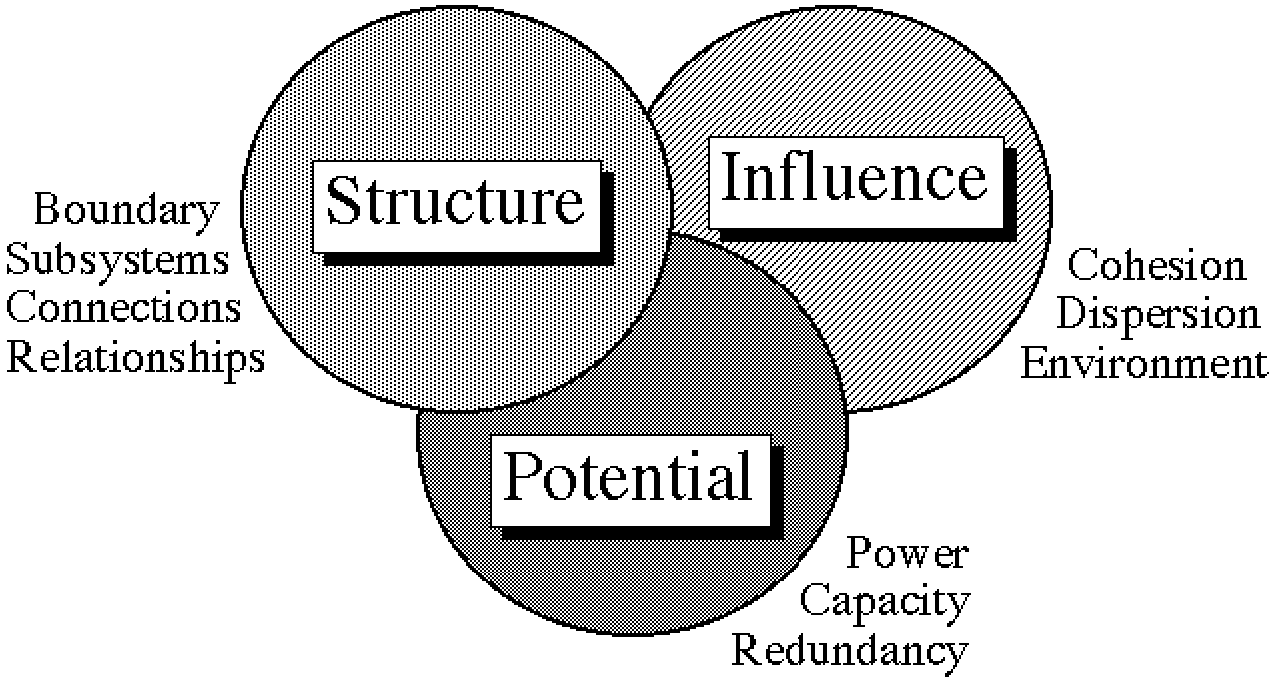


Figure 33: The Generic Reference (Form) Model

As with previous parts of the GRM, the behaviour model features may be tabulated:

Sensation interpretation

- Tacit knowledge, low-level knowledge of simple everyday things, e.g. “that things fall under the influence of gravity”.
- World models, perceptions of how the world is populated, within which representations of things behave according to tacit knowledge.
- Cognition, recognizing and interpreting sensations, external and internal to the whole system.

Belief system

- Beliefs, mutually consistent pre-conceptions of how the world behaves/should behave.
- Rôles, categories and pre-conceptions of rôles that should/do exist.
- Values, ethics, morals, pre-conceived views of what is "correct’’ or "proper".

Behaviour selection

- Experience, that which has been learned through nurture, training, situations and events. May lead to predictable behaviour — "second nature".

- Constraint, those practicalities or perceptions which limit category and/or range of behaviour.
- Nature, inherited behavioural features such as instincts, character, etc...

Response stimulation

- Activation, the "drive" accorded to a selected behaviour. May be associated with nature.
- Motivation, the strength of intent. May arise from experience. Two forms: achievement; conformance.
- Stimulation, the product of motivation and activation in support of behaviour selection.

These features of the GR(B) M may be presented symbolically as in Figure 35.

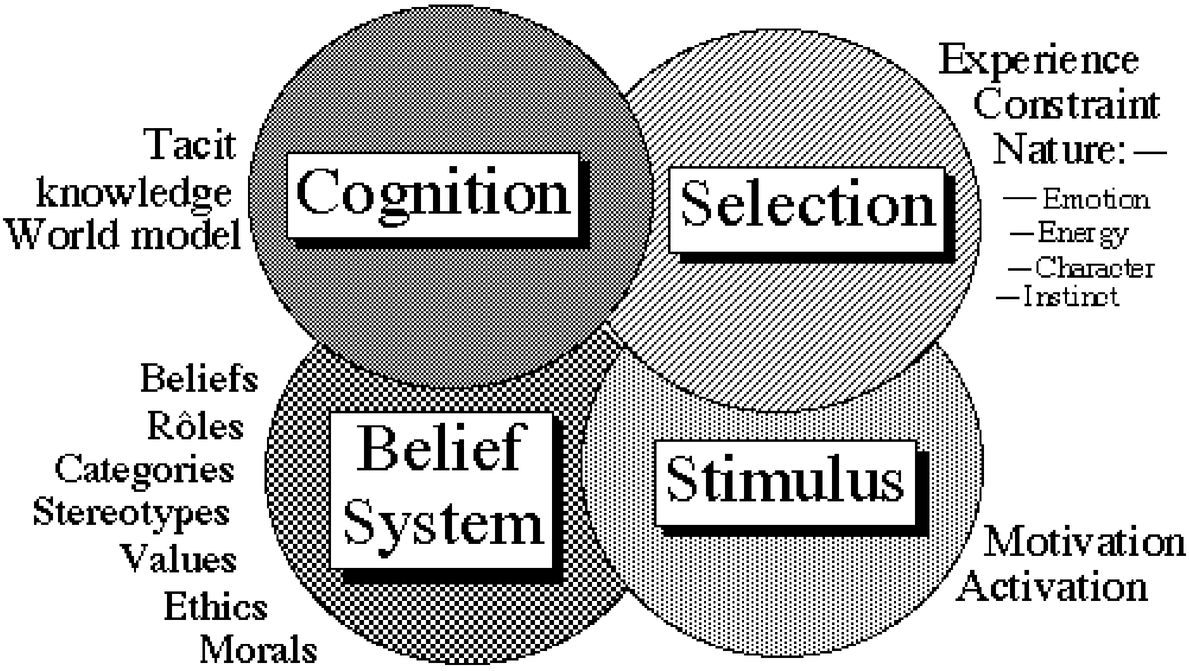


Figure 35: The generic reference (behaviour) model.

One other point about the models so far. We have seen that behaviour selection is essentially some contest or trade-off between nature and nurture. In the lifetimes of social species such as Homo Sapiens, social evolution occurs. Social evolution is the pattern of ideas, values, behaviours, that we learn from the moment we are born. Social evolution is the manners and lessons (for good or evil) which are drummed into each and every one of us until they become second nature. And that is the connection. Our belief systems are the seat of our second nature — beliefs, values, rôles, ethics, morals, these become our nature, not instead of our Darwinian heritage, but as a layer on top of that heritage, not separate from it, but modifying it. If we can accept that we have a second nature, then we can correlate Darwinian and social evolution models, comparing nature in one with second nature in the other.

Mission and behaviour models — Interactions

Although the parts of the GRM have been presented separately, they are not separate and cannot be considered so with any validity. Overlooking such mutual interactions is the hallmark of reductionist thinking and leads to a gross under-estimation of complexity. It is just such overlooking of interactions which allows people to convince themselves that battle simulations can be useful when they omit human behaviour.

Interactions are very strong between synergy management and the elements of the form model, for instance. Survival often invokes redundancy to tolerate damage or defect, as in the human design where we can all survive quite happily on only one kidney. To illustrate the importance of interactions between parts of the GRM, consider the relationship between the behaviour model and just mission management (part of the function model) illustrated in figure 36.

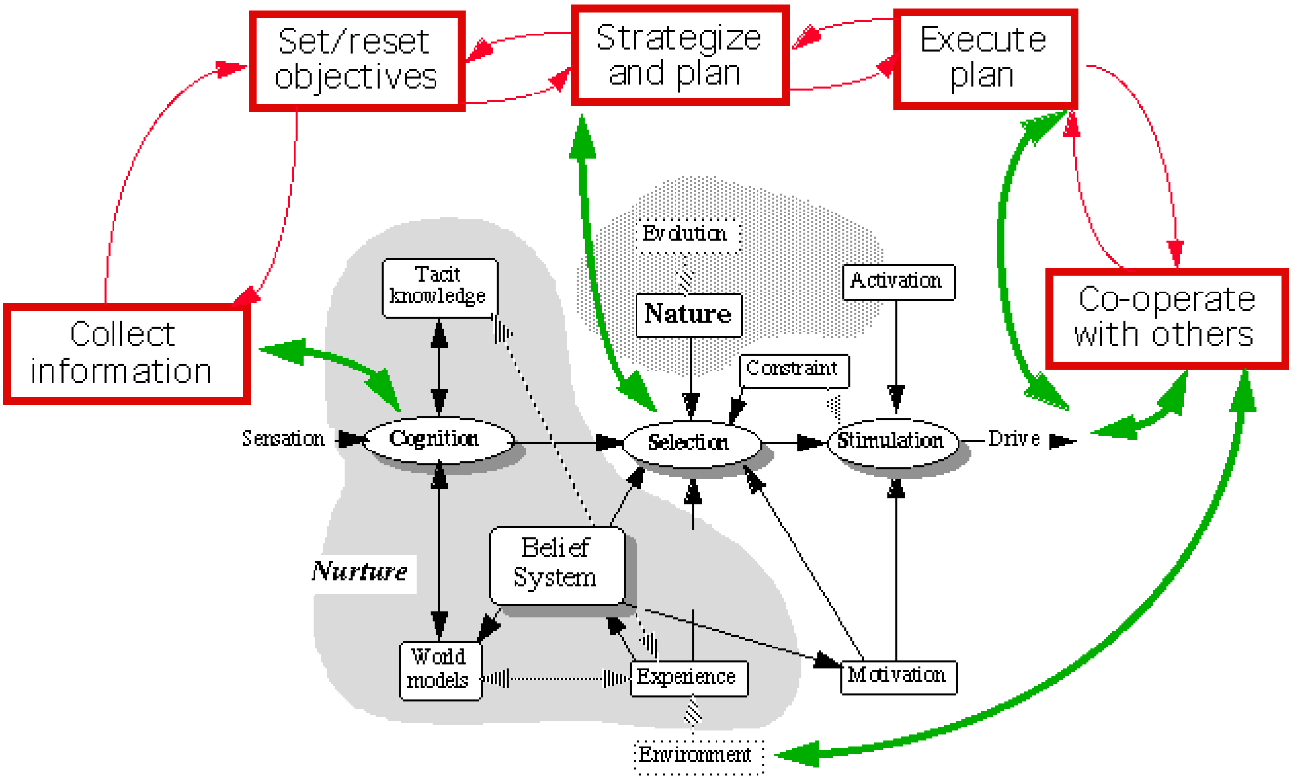


Figure 36: Interactions between the GR(B)M and mission management, part of the (GR(F)M.

In the figure, mission management is shown along the top, starting at the left with collect information, and finishing at the right with co-operate with others. A simplistic view might consider that operations management, say, was a matter of collecting all the necessary information, working out a plan and acting on it with other team members — i.e. mission management.

The figure shows differently. Information is interpreted, if recognized at all, through a filter of world models and tacit knowledge, both based on experience and influenced by belief; the idea of objective interpretation of information is immediately challenged. Similarly, acceptable strategies and plans are those confined within the boundaries of belief and experience. Other strategies will either not be thought of, or will be rejected out of hand as inappropriate — not because they are necessarily "wrong" but because they do not fit pre-conceptions and perceptual constraints.

Belief can be seen from the figure to be at the very heart of behaviour management — we shall return to belief systems later, but for the moment, consider the following quotation:

> “Could it be that we substitute our beliefs for rational thought in an effort to cope with the complexities of the world around us? Beliefs certainly allow us to size up situations rapidly — and perhaps wrongly.”

The annex to this chapter contains an example of the GRM, used to support the development of a complex design concept for a manned base on the far side of the moon. Readers may, if they choose, skip over the annex or read it at their leisure.

Thinking in loops

The generic reference model proposed what one might find inside any system. That is fine so far as it goes, but it offers a rather static view; the interactions between any system and its environment determine the dynamic behaviour in which we are often just as interested.

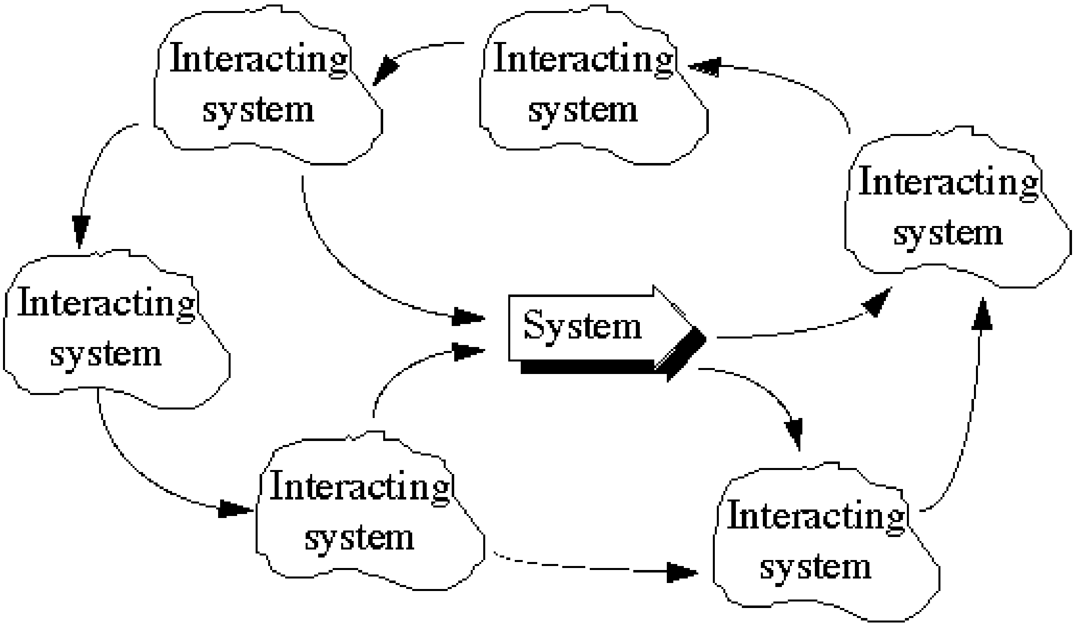


Figure 37: A system, any open system, is shown interacting with others as it transforms inflows to outflows. Since systems exist in a never-ending web of interactions, some of those interactions connect outflow inevitably back to inflow, probably via some transformations.

Any system's outflows inevitably interact with other systems in the environment to affect its own inputs — see Figure 37. Introducing a new system into an existing set disturbs all of them, existing set and newcomers alike. Subsequent dynamics may militate against or for sustaining the new system, and could be inimical to the set.

In the general case, as the figure suggests, predicting the behaviour of the new set may be very complex, and yet we commonly launch new systems into existing environments without too much thought, witness the current social experiments in the UK with schools, hospitals, railways, utilities and many more. I call them experiments because, as far as one can see, they have been neither tested nor thoroughly modelled prior to introduction and, despite the protestations of politicians to the contrary, the outcome of such careless changes is really quite unknowable. Note, I do not propose that the outcome need be "bad", simply that we have no way of knowing, since the changes were driven by political and economic ideology, not as a result of some careful trial and subsequent correction of deficiencies.

One way to explore such situations, and therefore to have some prospect of anticipating the unexpected, is to use models, to place the new system into the existing set of systems, but in a computer simulation before doing so in the real world, to reduce risk.

Thinking in loops, as in the figure, encourages:

- Completeness of sets of interactions.
- Identification of the "relaxation condition" of multiple interacting systems, the likely eventual state of the set.

When using causal loop representations:

- Open interacting system loop models tend towards a stable state — static or dynamic — representing some minimum lattice energy condition.
- The outcome of model runs may be counter-intuitive, and so...
- There is potential for predicting counter-intuitive behaviour of complex systems.

Counter-intuitive dynamic behaviour

As an example of counter-intuitive behaviour of a system, consider the models of figure 38. The two models are very simple, and are identical in shape and general operation; they are concerned with the supposed value for money provided by training and education respectively.

On the left, training is presumed to be a short affair lasting some 3 months only, resulting in staff trained to a specific skill. That skill lasts for some 24 months, due to staff being posted to other duties, the skills becoming redundant as new facilities are introduced, etc…

On the right, the same staff population is given education which, being broader and seeking to instil understanding rather than specific skills, takes longer — 12 months in the model. On the other hand, that understanding is assumed to last longer, too — for 8 years in the model.

So here is the dilemma: which model results in best value for money as seen from the perspective of the organization; which costs the most; which gives the greater population of either trained or educated staff at any time?

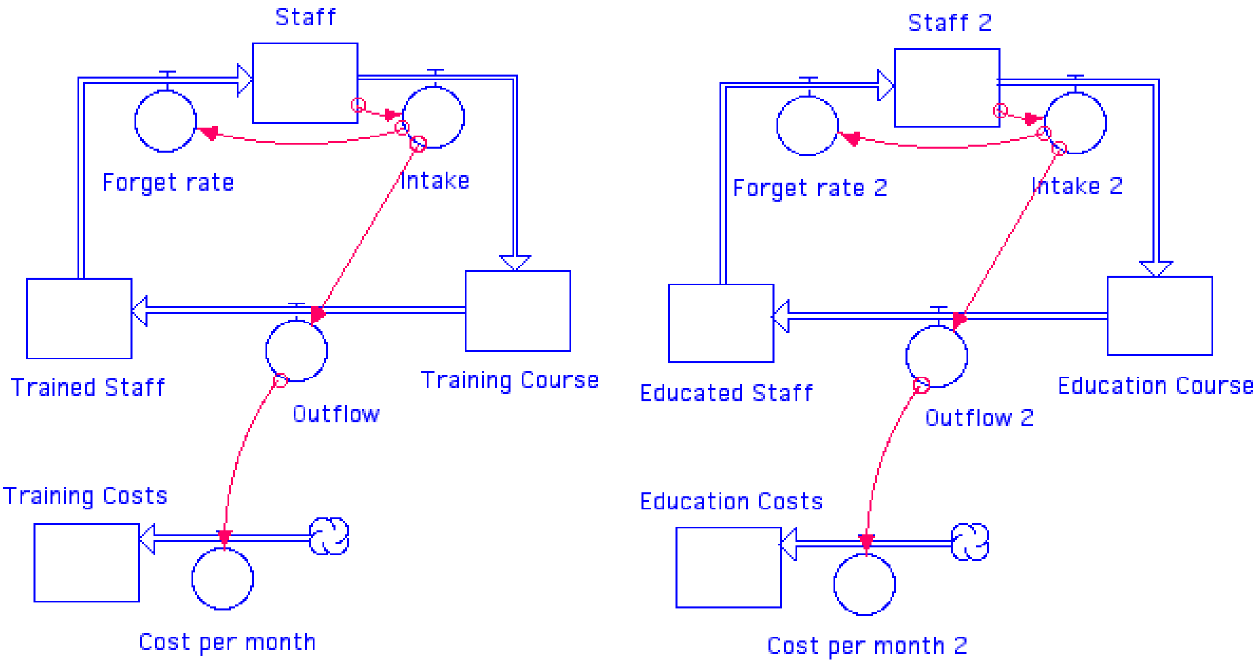


Figure 38: Two models representing training and education respectively. In the models, training is assumed to refer to short-lived, specific skills, while education refers to longer-lived, but rather more general levels of knowledge and understanding. Questions arise about the relative cost-effectiveness of the two approaches for middle-ranking staff in an organization over an extended period of time.

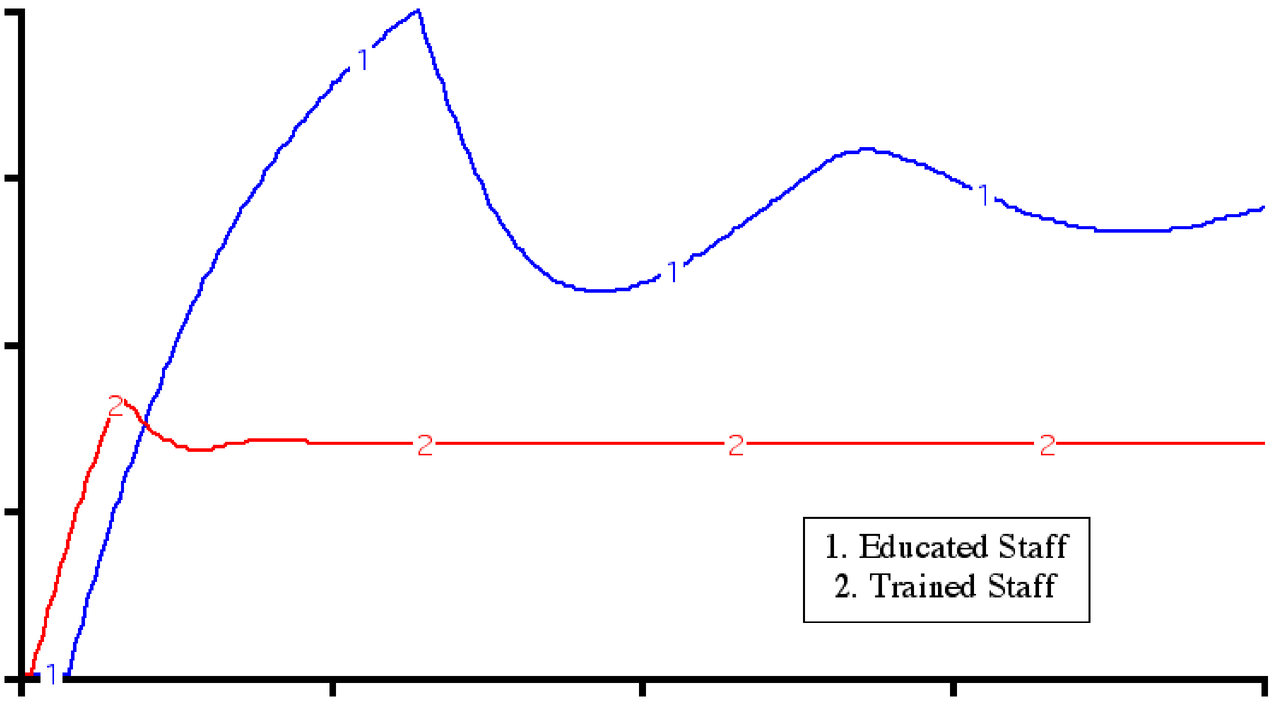


Figure 39: The graph shows the number of educated and trained staff predicted from the closed loop models above.

Figure 39 shows the numbers of educated staff to be double that of trained staff, once initial turbulence has settled out of the model. Other results show that the cost of education is only half that of training, long-term. All other things being equal, then, education gives four times the value for money, since it results in twice the numbers for half the cost. Of course, all other things will not be equal. Any organization needs both trained and educated staff. But it is amazing how often such spurious arguments as that about the cheapness of shorter-duration training VS. that of longer duration education can, and do, arise.

Finding the common exchange medium

In any complex system there are certain "fluxes" that flow through its various parts. Finding the flux is important, but can prove difficult, and is best explained by example.

What is it that runs through a car industry? Many people might say "money" and they would not be wrong, but money flows through every business, and choosing money may not result in a good differentiator for the car industry. Besides, money tends to flow in the opposite direction to "things". Instead, consider the flow from resources through manufacture, assembly, sales, usage and, finally, scrap/recycling. Keeping the flow going is the one essential, unifying theme to which all parties in the industry, be they suppliers, assemblers or scrap merchants, can subscribe.

What is it that is common to members of a political party? Is it, perhaps, a shared belief system, an Ideology. Is seeing the world through the tenets of "the one, true belief system" the essential, unifying theme?

What is common to the participants in an air defence system? The continuing provision of weapons to the point of delivery against an encroaching enemy is, perhaps, the single unifying theme.

These unifying fluxes are important to identify. Commercially, there tend to be two flows running in opposite directions. In the car industry, for instance, if supplies run clockwise around a system from second to first tier suppliers, to assemblers, and so on, then money runs counter-clockwise around the same system.

Thinking in straight lines — Occam's razor

Sometimes, when there is insufficient information, or when the situation is too complex to even start sensibly, then some way of cutting the Gordian Knot becomes necessary. William of Occam (c.1280-1349) gave his name to one such method — Occam's Razor: entia non sunt multiplicanda praetar necessitatum — beings ought not to be multiplied, except out of necessity. There are many interpretations of William of Occam’s famous dictum. Mine is as follows;

> “If there exists a number of potential paths, routes options, etc, between which it is necessary to choose, and if there is insufficient data upon which to make a judgement, then choose the path, route, or option which contains the least steps or parts.”

The reasoning is simple. For each step in any process, there is an associated degree of risk or uncertainty. The uncertainties for each step multiply together, making the path with more steps more uncertain. Given no other data about the actual uncertainties, then, the only sensible judgement is to choose the option with the least parts, steps, etc. The dictum also results in choosing the simpler in favour of the more complex. We see today many large-scale project failures and cost overruns which would have been avoided if Occam's Razor had been applied.

Interestingly, the Japanese seem to have embraced Occam in their approach to lean production, where the cry is to streamline and simplify rather than to cope with ever-more complexity as we in the West seem intent on doing.

Example of GRM in action

The generic reference model may be used in several ways:

- As a guide to identifying the parts of a complex system.
- As a check to see that the design or description of a complex system is complete.

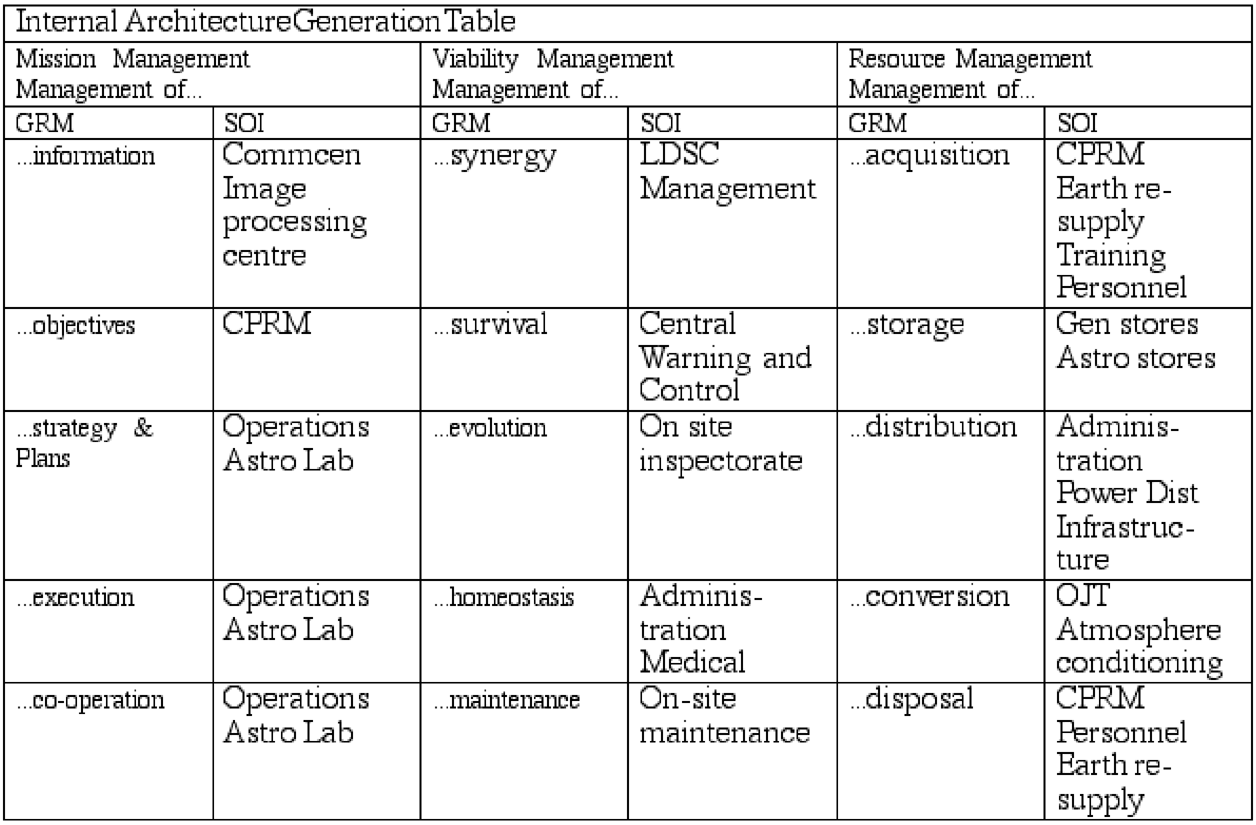
- As a basis for rapid design of a new system, especially one without precedent.

Designing unprecedented systems is by far the most fun, so consider a new base, to be established on the far side of the Moon, with the dual purposes of:

- Housing and operating a deep space radio telescope.
- Supporting missions to the solar planets, both for outgoing missions and particularly to acclimatize returning missions.

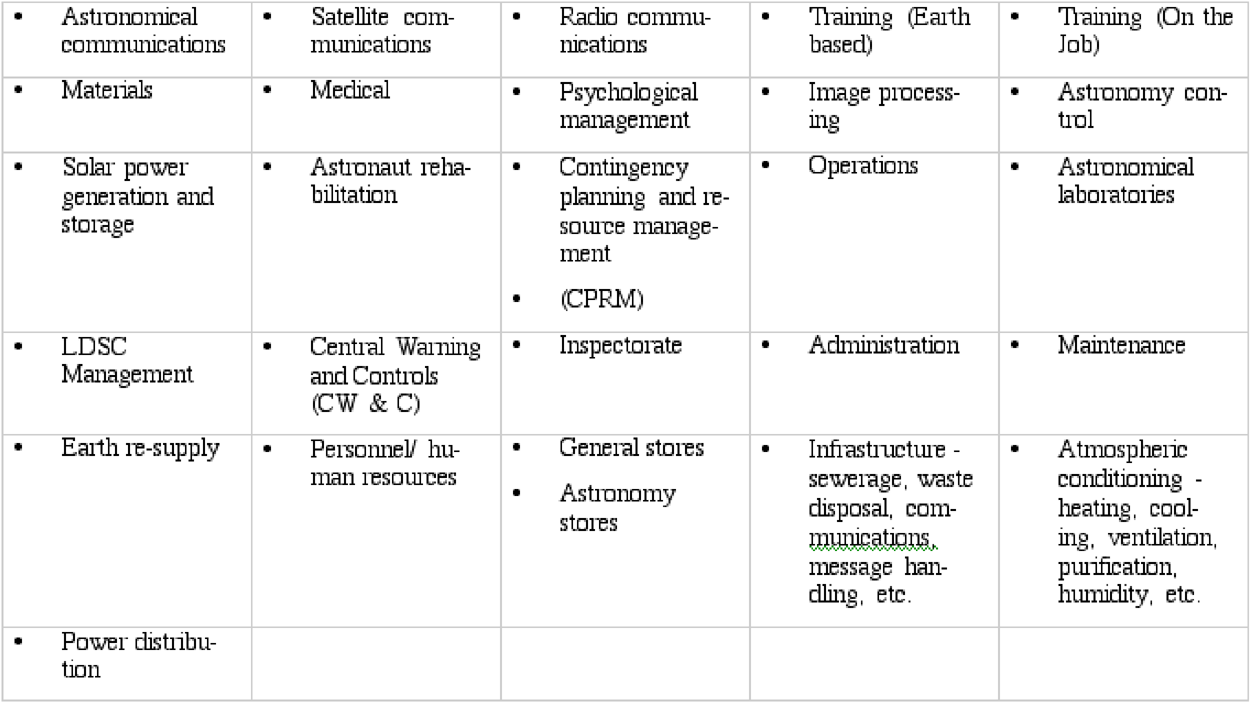
The design may be approached by presenting the GRM in tabular form.

Table 1: GR(F) Model table for lunar base



Internal ArchitectureGeneration Table					
Mission Management Management of...		Viability Management Management of...		Resource Management Management of...	
GRM	SOI	GRM	SOI	GRM	SOI
...information	Commcen Image processing centre	...synergy	LDSC Management	...acquisition	CPRM Earth re-supply Training Personnel
...objectives	CPRM	...survival	Central Warning and Control	...storage	Gen stores Astro stores
...strategy & Plans	Operations Astro Lab	...evolution	On site inspectorate	...distribution	Adminis-tration Power Dist Infrastruc-ture
...execution	Operations Astro Lab	...homeostasis	Adminis-tration Medical	...conversion	OJT Atmosphere conditioning
...co-operation	Operations Astro Lab	...maintenance	On-site maintenance	...disposal	CPRM Personnel Earth re-supply

Table 1 shows the elements of the function model, alongside spaces where the designer may write in the functional components of the lunar base which are to provide/create/enable the function. So, information is to be acquired and handled by the Commcen (Communications Centre) and by the Image Processing Centre, evidently for sensor images. Similarly, objectives are to be established by CPRM (Contingency Planning and Resource Management). Continuing to the second column, synergy is the responsibility of the LDSC (Lunar seep space centre) management. Under resource management, there is the management of conversion, covering both OJT (On the job training of staff) and atmosphere conditioning, showing that resources include all resources, human and material.



Astronomical communications	Satellite communications	Radio communications	Training (Earth based)	Training (On the Job)
Materials	Medical	Psychological management	Image processing	Astronomy control
Solar power generation and storage	Astronaut rehabilitation	Contingency planning and resource management (CPRM)	Operations	Astronomical laboratories
LDSC Management	Central Warning and Controls (CW & C)	Inspectorate	Administration	Maintenance
Earth re-supply	Personnel/ human resources	General stores Astronomy stores	Infrastructure - sewerage, waste disposal, communications, message handling, etc.	Atmospheric conditioning - heating, cooling, ventilation, purification, humidity, etc.
Power distribution				

Table 2: Behaviour model for lunar base

(The functional elements above represent individual, isolated, disconnected variety — we have developed a complex, disordered view as the first stage in a three-stage process see page 37.)

Closely associated functional components can be co-located in the development of a physical design from the functional components — see figure 40, which uses the genetic algorithm method illustrated in figure 19.

(Figure 40 represents the second stage in the three-part process — connecting the variety to show sets and systems, so that we may move towards the third step — reduced entropy, as follows.)

The core design shown in figure 40 can then be connected to all the necessary and associated external inflows and outflows, required and un-required, as shown in figure 41.

(Figure 41 represents the simplified, reduced-entropy final state, the third stage in the three-stage process of creating a reduced-entropy design concept.)

This example shows only one way in which the GRM is useful. The principal alternative use would present itself when seeking to understand, and establish credibility/completeness of, a system.

For instance, auditing a system design, or reviewing a system to understand the cause of failure, or seeking to improve some limited capability.

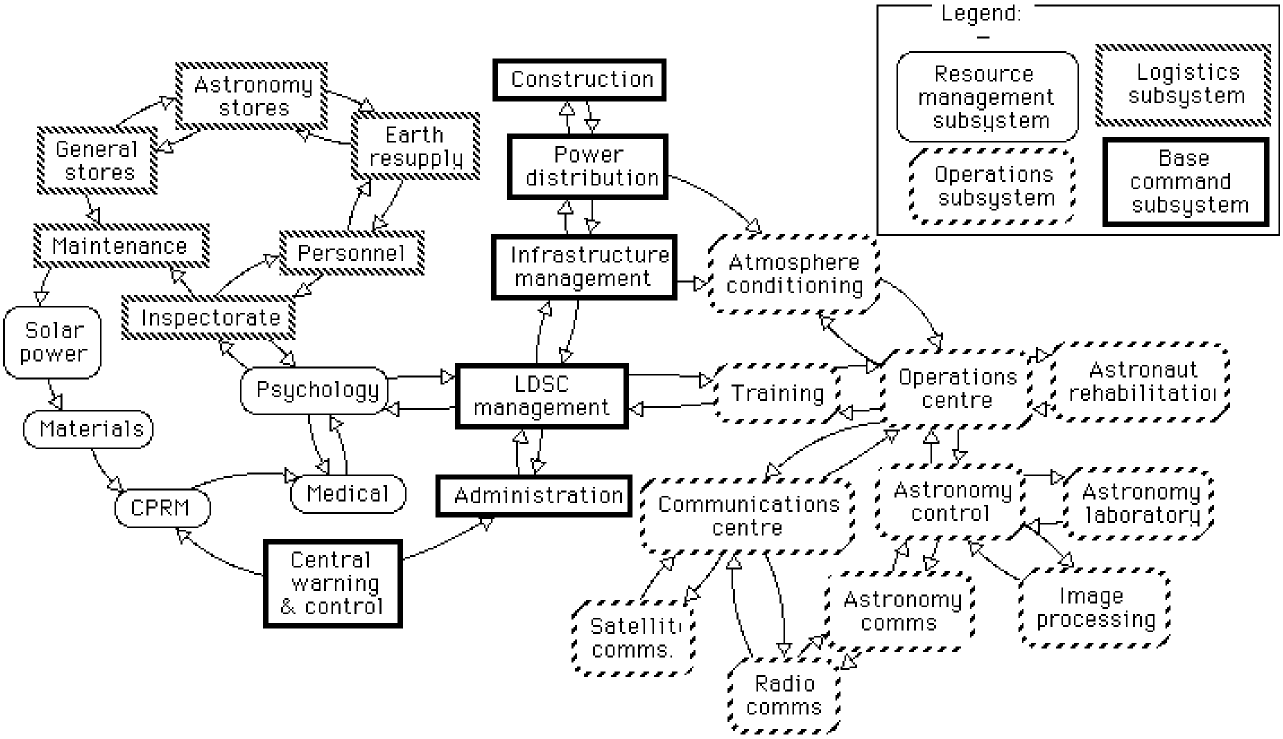


Figure 40: The conceptual organization of an unprecedented lunar deep space centre

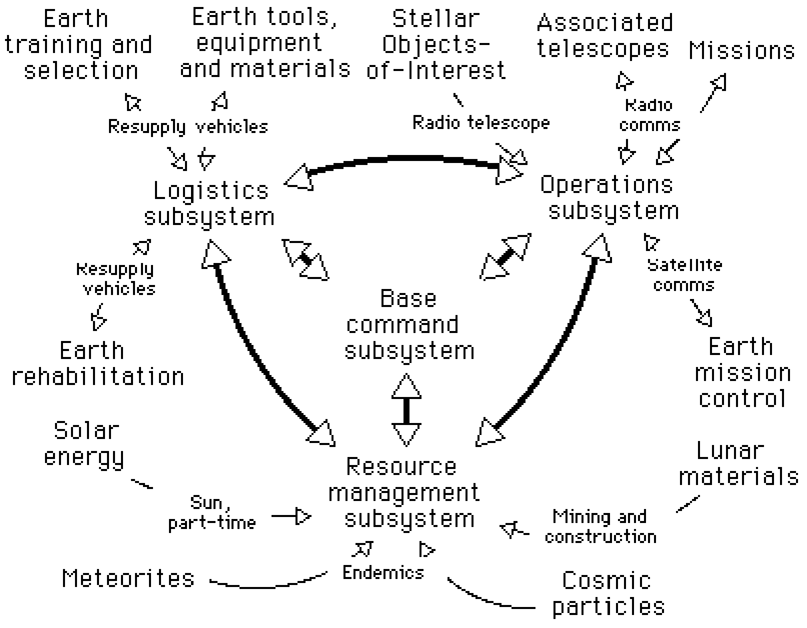


Figure 41: Connecting up the lunar deep space centre design

Vantage points

> “It is not best to swap horses while crossing the stream”
> — Abraham Lincoln, 1809-1865

Archimedes, 287-212 B.C., is reputed to have said: "Give me somewhere to stand, and I will move the Earth." (Pappus, Synagoge, ed. f. Hultsch, Berlin, 1876-8, VIII, 10, xi). Archimedes had reasoned that he might be able to weigh the Earth if he could balance it on a fulcrum, like a ball on the end of a lever. In arriving at this idea, Archimedes had already addressed the most difficult part of weighing the earth — projecting himself to a "third person perspective" from which he could see the problem. Many of his contemporaries could not see the issue so simply.

This capturing of vantage points is a special skill, which can be practised and improved, there seem to be several vantage point categories:

- Spatial, like Archimedes.
- Temporal, as in time-lapse photography, speeding up time to reveal underlying features not evident at normal speed.
- Hierarchical, as in looking across a whole economy or industry, rather than at a particular part.
- Analogical, by comparing understood with less well-known.

Third-person vantage point

Most vantage points seem to be third person views. I recently came across an example of a third person vantage point at a company that invents virtual reality arcade games. One of the games represented formula 1 motor racing, and the software was being tested by one of its authors. He found himself, in virtual reality, approaching the first bend when a car in front reared up and descended on him. Although this was only a computer simulation, and although he had written much of the simulation himself, he nonetheless felt quite afraid. As a result, the software has been rewritten so that, in the event of imminent danger to the game player, he or she is snatched to a third-person viewpoint. In the case of motor racing, the "at-risk" player is snatched to a track-side view and sees the crash happening as though to someone else.

Temporal vantage — Project VS functional organization

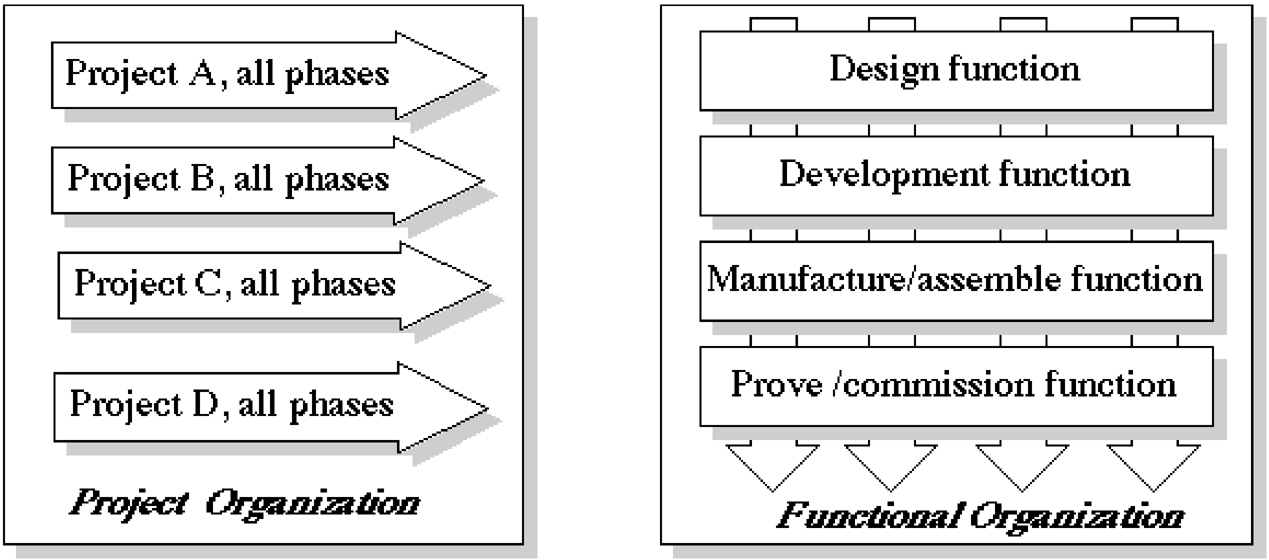


Figure 42: Project versus Functional Organizations

Figure 42 shows two archetypal ways of organizing a typical manufacturing company. One approach is to consider that the organization is made up, essentially, from a number of projects, running in parallel and with little or no cross-feed. The second approach is to organize around major functions that have to be performed, such as design, development, manufacture and commissioning.

Comparing these two archetypes is rewarding. The project organization has clear goals and each project team is aimed at its respective goal. It seems to be, potentially at least, lean and efficient. The functional organization, on the other hand, quite often turns out to be more effective, because the people become expert at their functions, and can carry over learning between projects.

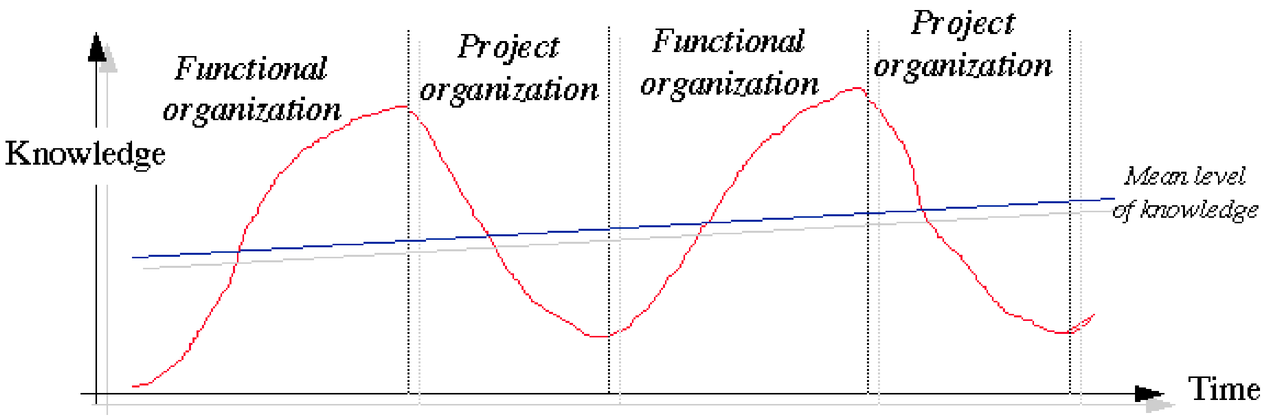


Figure 43: Organizational dynamic stability

Organizations typically switch between project and functional organizations periodically, and at first it seems hard to understand why. Looking at an organization over several cycles of functional/project change, however, reveals a rationale for the switching which may not be evident even to those in the organization.

During the functional phases, the functions learn and grow and become more expert as an organization. This results in increasing effectiveness, but also in increasing cost — which comes to the attention of accountants. Now accountants have a simplistic view of such things, and they blow the whistle because they do not understand, and cannot measure, effectiveness. All they see is increased overheads. The subsequent switch to project organization makes them happy, but unfortunately for the organization, its ability to learn is virtually destroyed by the imposition of sharp internal barriers between the projects, which allow neither ideas nor people to cross. The organization is now efficient, however. Passage of time sees two factors emerge:

- People working in parallel projects start to talk, exchange ideas and experiences, and cross links between projects become institutionalized.
- The organization finds new business more difficult to acquire as it is unable to compete with organizations that have kept on learning, and people recognize the need to become more expert.

After a suitable interval, the company switches back to functional organization, with all the accompanying disruption, and the process of organizational learning recommences.

Figure 43 shows what is going on. The organization is surviving by increasing its average knowledge and capability (effectiveness) while holding its average overheads in check. Switching between project and function is the stable state!

> “Of course, there may be a better way to grow a company…”

Temporal vantage — Successive fashions

One advantage of the temporal viewpoint is that it enables one to see fashions and fads more clearly. Consider outsourcing, the idea that a company should employ outside contractors to undertake virtually anything except its core business. Part of the approach is so-called Market Testing. We know about market testing; that is what those people who come up to you in the street with some new product are doing, yes? No. One of the ways to recognize fads and fashions is by the use of meaningless titles e.g. market testing. In this case, market testing is the process of offering a company’s internal functions to the market place so that others may bid for it. For instance, a company making shoes may decide to outsource its information systems (IS), and would present a tender document to various IS companies in the hope that a bid would undercut their internal costs for the same activity.

Now, you would go far to find a riskier strategy than this one. Not only are you letting another company handle your "crown jewels", but you are burning your boats in the process, i.e. once the step is taken, it would be very expensive and difficult to retrace. Moreover, once the IS company has your business, you become dependent on them — which can prove an uncomfortable position. Last, but not least, there is inadequate capacity in the IS sector to cope with a sudden increase in demand.

So, is outsourcing sensible, good business or fashion? Let us look at recent fashions, using our temporal viewpoint to telescope the years:

1. Mid eighties — corporate diversification is the panacea as a hedge against changing environments. Its crie de coeur might have been "flexible portfolios for survivable revenues".
2. Late eighties — consolidation (or divestment, a more sensible term) became the panacea when diversification gave companies new responsibilities they did not understand and failed to manage. The consolidation crie de coeur? — "stick to core business, it's what we understand".
3. Early nineties — outsourcing or market testing, the panacea by reducing right down to core business, whatever that might be. Again, a special crie de coeur — "get rid of overhead drivers, outsiders/specialists can do things better, we are only good at our core business… by the way, what is our core business?".

Seen in context, outsourcing is just the latest in a long line of unsuccessful fashions. Not that outsourcing need be a bad thing. There are some prerequisites for successful outsourcing, however, as practised successfully around the world.

The outsourcing dilemma

To explore this topical issue further, consider a car manufacturer. What is the core business? The company could:

- Subcontract manufacture of engines, bodies, electrics, hydraulics, instruments, seats, everything.
- Outsource marketing, corporate IT, accounting, selling/franchising...
- Employ subcontractors to be the actual assemblers — where is the limit?

Looking from this "piecemeal" perspective offers no answers — a "systems perspective" is called for, and may be found by adopting an analogical viewpoint.

Analogical vantage

To examine IS outsourcing let us use the project versus function model developed above. To make use of this model we need to move up in hierarchy level and look from a third person perspective on a set of interacting industries. We can then consider whether successive fashions are more a group-subconscious switch between effectiveness and efficiency, gaining knowledge, then trimming fat.

To acquire a rational view of outsourcing let us look around world for other forms of outsourcing, examine environments, successes, failures. The global car industry has outsourced for years; it is popular in Sweden and Japan, yet unpopular in the USA. The reason for the differences is not hard to find; outsourcing depends upon the existence of a robust small industry environment, less evident in US.

From this and other evidence, we may make the following (rather obvious) deduction: the ability to outsource is determined principally by the environment and its ability to sustain and support outsourcing, rather than by corporate intent. If fashion dictates that outsourcing shall happen, then the IS environment — which takes many years to evolve — may well be swamped.

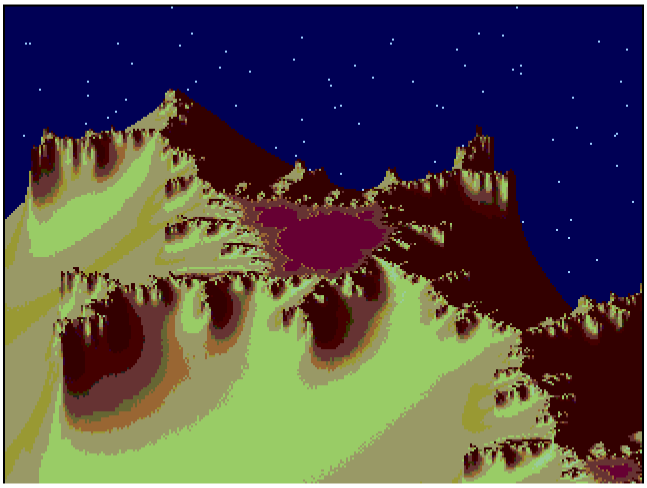
Is it possible to predict the outcome? It is always dangerous to predict the future, but we do have the function/project model to guide us. In many ways, outsourcing parts of a company's activities is analogous to switching from project to function, but at one hierarchy level up.

That suggests strongly that:

- Outsourcing corporate IS will stimulate growth of IS companies.
- IS companies will:
  - - learn,
  - - become effective,
  - - grow fat,
  - - become less efficient
- Corporations will regain their own IT after a suitable interval, i.e. switch back from function to project, and a switching cycle will ensue.

Of course, there is more to it; for a start, we have no idea of the length of the cycle, so predicting when the cycle will repeat is difficult. On the other hand, we might consider that project/function switching is a stable state in which companies survive and grow. Perhaps outsourcing/in-sourcing is a dynamically-stable state. There may be a better way to grow a company...

Summary



Fractal 5: 3-D view of Mandelbrot.

Part 2, Getting a Handle on Complexity, has presented a variety of ways of looking at complex systems and situations. All are designed to get to the essence of a situation which can be expressed in a simple, visible, easily-understood manner. Cutting through the veil or web of complexity is never easy, but — like most things in life — does seem to become easier with practice. Following parts will make use of these ideas.

The social genotype

Models of evolution

> "Evolution is a change from a indefinite incoherent homogeneity to a definite, coherent, heterogeneity."
> — Herbert Spencer, 1820-1903

Increasing natural order

Food and Inheritance

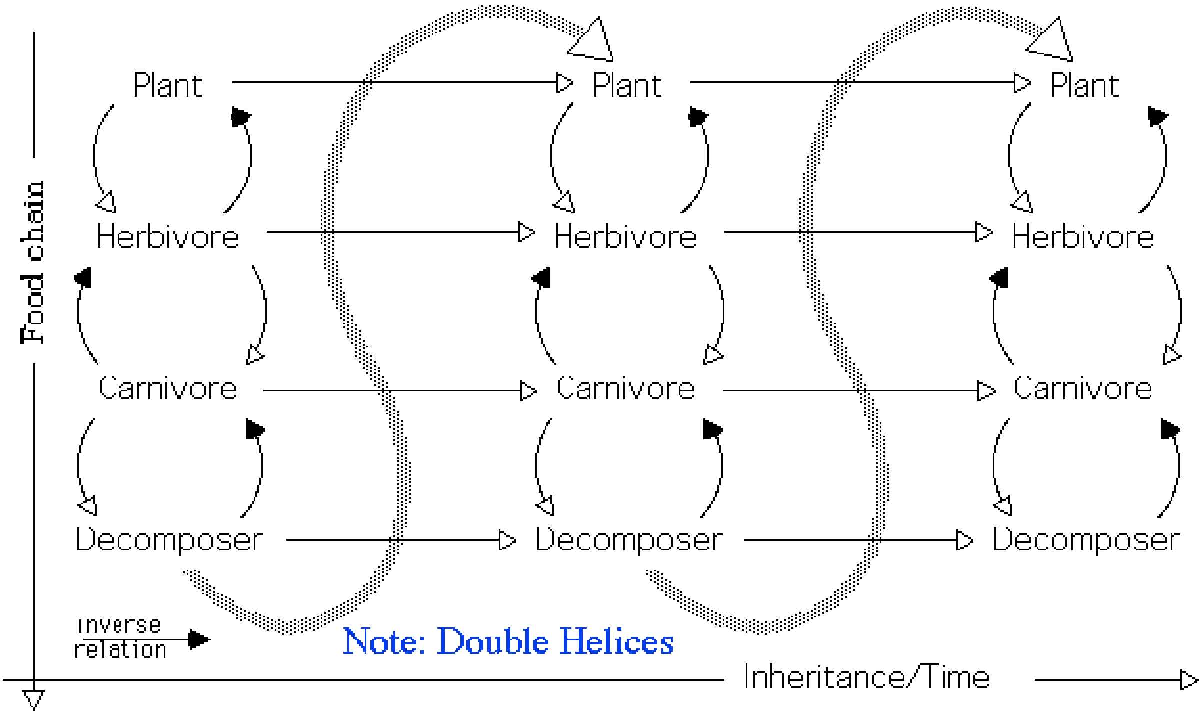


Figure 44: The matrix of life. Food chains run vertically up and down the figure. Inheritance chains run horizontally. Experience tells us that the two orthogonal chains create a highly stable structure, evolving slowly with time. The food chains work both up and down to produce the closed double helix shape. Carnivores reduce herbivores reduce plants. Plants increase herbivores increase predators. Decomposers/saprobionts decompose animals and plants to recycle through the food chain. Reproduced by permission of Plenum Press.

Figure 44 shows a typical food chain, reducing entropy as it goes down the page from plant to predator, at least in the sense of building proteins. Similarly, but on a different time scale, inheritance travels with time from left to right, also adapting and refining the species to become more efficient operators within their environment which, of course, includes the other species. We know this complex web of interactions to be very stable and to evolve only slowly over time. While at close quarters, the interactions between the species may seem chaotic, with a multitude of uncorrelated activities, the overall pattern at a distance is stable, survivable, adaptable and indeed powerful. The second law of thermodynamics may apply at the micro level, and at the universe level, but it seems to be falling short of an explanation at the level of Figure 44.

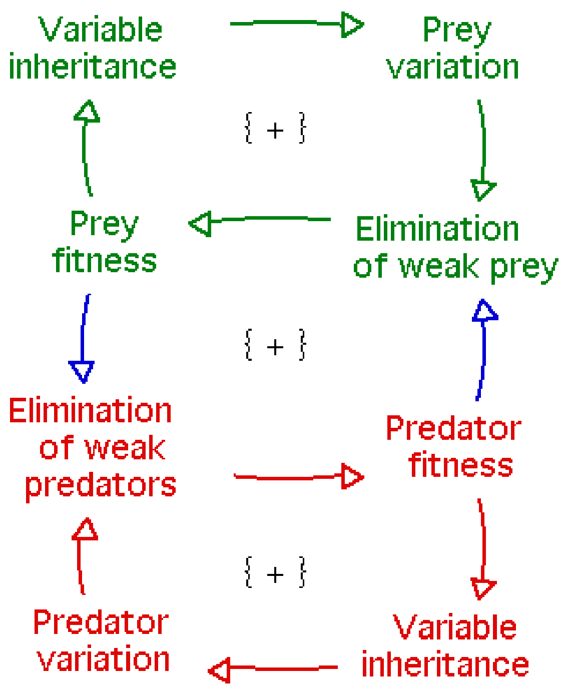


Figure 45: Prey-predator symmetry

Figure 45 shows a simple but subtle model of prey/predator interactions. Fit predators eliminate weak prey — centre loop — increasing the average fitness of prey. Fit prey breed — top loop — and produce variable offspring, about a mean of survival fitness. Weak offspring fall prey to predators.

The figure is symmetrical, suggesting a very similar story for predator inheritance. Fit prey escape from weak predators, which die or fail to breed, eliminating weak predators and leaving the average predator fitter. The fitter predators propagate — bottom loop — giving variable inheritance to their offspring. Weaker offspring cannot catch fit prey and so die off. The symmetry of this model is striking — prey depend on predators as much as predators depend on prey!

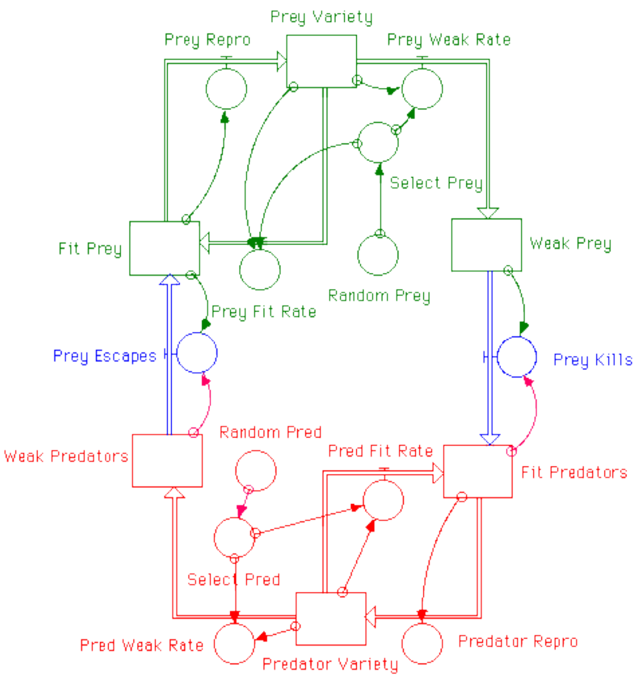
Summarizing, the net results of loop interactions are as follows:

- A multitude of concurrent, uncorrelated attempts to improve prey/predator performance are continually in play, leading to...
- ...elimination of weak varieties,
- selection of prey-predator combinations best able to survive as complementary sets.
- Gradual improvement in fitness = best use of energy in environment.
- Development of species genotypes, tuned to each other and to environment.
- A continual test environment which, once again may seem to be at the "edge of chaos"? when viewed from close to.

Note the closed double helix in both figure 44 and figure 45. This shape keeps reappearing, and will be the subject of further discussion. Also, note that, instead of complex models, we are modelling variety as a commodity. That is an unusual, and powerful, ruse.

Closed double helix — Dynamic model

Figure 46: Simulating Prey/Predator relationships.



The model of figure 45 can be represented in a computer simulation, figure 46. The simulation is directly mapped from figure 45, with the same three loops apparent. Starting from fit prey, the simulation shows prey Reproduction as a rate, dependant on the number of fit prey, leading to prey variety; this is the path of inheritance, and offspring have a degree of variety as part of reproduction. Some of that variation may result in fit offspring, which rejoins the fit prey, but other variation results in weak prey. Select prey allows the modeller to choose the proportion of weak to fit offspring; for the following results, it was assumed that 50% were fit, 50% were weak. Predator population is modelled in identical fashion. for simplicity, prey and predators have been given equal starting numbers; the model executes just as well if it is assumed that, say, there are many more prey than predators.

Double helix dynamic stability

The results of the predator and prey simulation is shown in figure 47. At the top, the predators and prey interact to produce dynamically stable populations. Indeed, the predator/prey graphs overlap to produce another double helix.

Perhaps the most surprising result from the simulation arises in the lower of the two graphs, in which the ratio of fit to weak predators is examined. Remembering that the inheritance weak/fit ratio is set at 50% for both predator and prey, the resulting overall population shows a ratio of some 300 fit to about 4 weak, or about 1.3% weak only. Why? For both prey and predator, the fit are preserved to reproduce, and the weak go to feed the opposing fit.

This interlocked, symmetrical behaviour drives out weakness in each species. It also raises some interesting questions about humans. There is considerable research at present, particularly in the US, aimed at establishing some genetic basis for homosexuality. Homosexuality may be genetic, but it may be a cultural, or a learned phenomenon. The issue is surrounded by controversy, and I have no wish to enter that particular arena. However, the model does suggest that any characteristics amongst offspring that reduce the ability to reproduce — for any or all reasons — would inevitably, over a period of evolution, be reduced to a low level. If that is so, then the percentage of the population genetically unable to breed, for whatever reason, would tend to be very small, and the percentage of genetically homosexual humans even smaller.

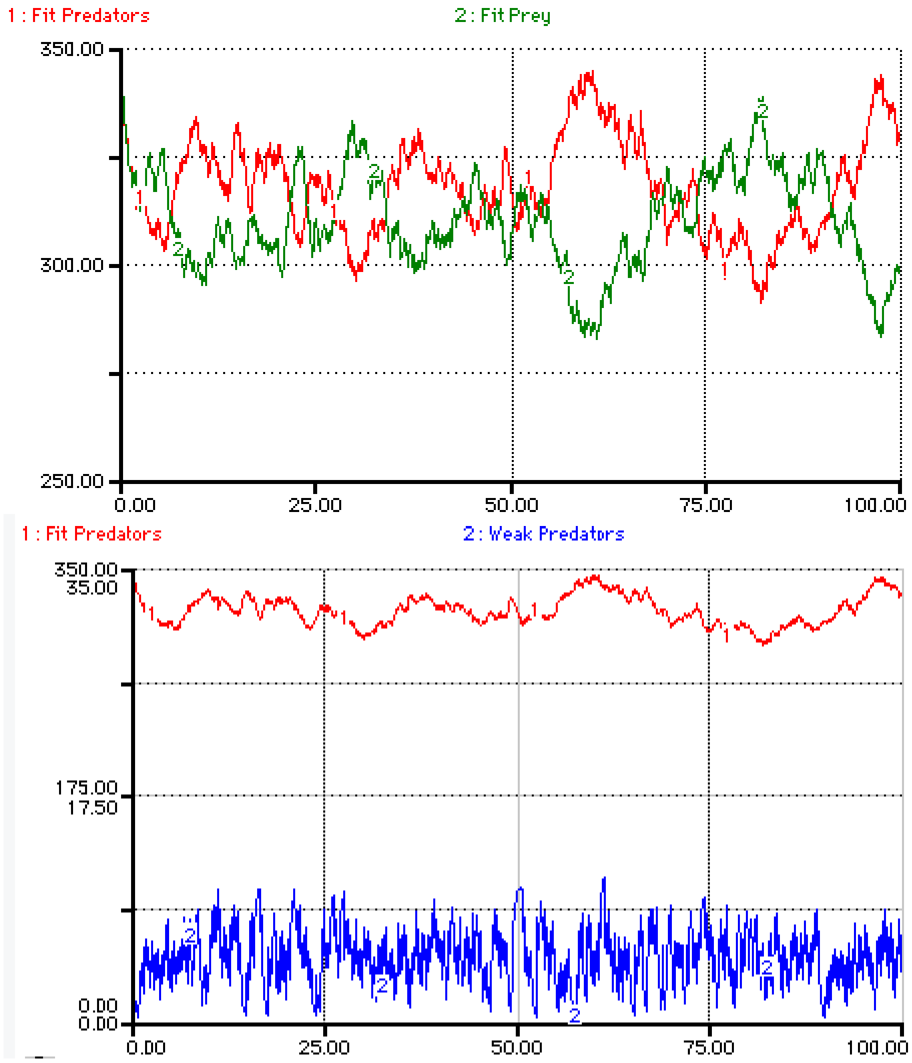


Figure 47: Prey/predator simulation. Note the different Y-axes on the lower graph.

One other aspect of the model is the recurrence of the theme: short-term unstable, long-term stable. The model, distributing the offspring fit/weak ratio about a 50% average, reflects the generation-by-generation variation in actual figures. Within a generation, the behaviour may seem random or chaotic; over many generations, the peaks and troughs are seen as varying about an average.

Some deductions emerge from the simulation exercise;

- Individual species "improvements" are unlikely to succeed. For instance, if an improved predator kills more prey, there will be a shortage of prey, reducing the food for the improved predator. As the inter-twined helices of figure 47 suggest, any variation by prey or predator is countered by a consequent variation in predator or prey.

- Simultaneous improvements are more likely to succeed, however, such as: improved grass, more able herbivore, smarter predator all arising at the same time.
- There is a low probability of such simultaneous improvements in several species, which may...
- ...help to explain discontinuous evolution.
- There must be a relatively low variability within a species, generation-to-generation, because...
- ...high species variability would produce a large proportion of non-viable offspring, reducing prospect of species survival.

We might be able to extract some business lessons from the modelling, too: perhaps we should concentrate more on improving the overall chains of interactions within and between organizations, rather than concentrate on the links as total quality management seems to do; perhaps, too, we should emphasize slow evolution rather than revolution!

Abstracting the closed double helix

The symmetry between predator and prey relationships is so striking that it indicates a path for extending and adapting the simulation model, perhaps into something much more useful.

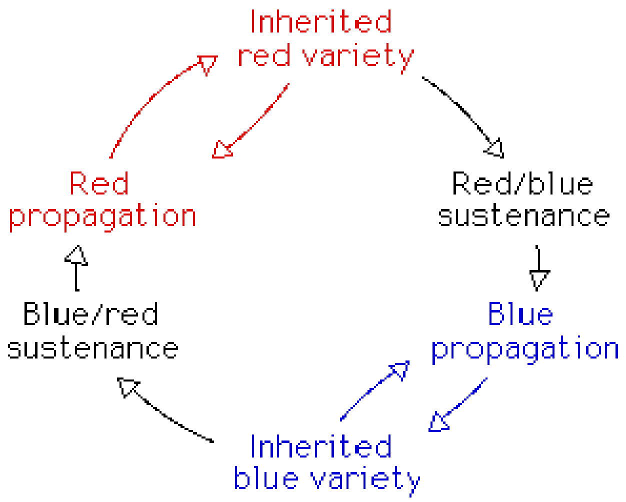


Figure 48: From prey/predator to red/blue.

Figure 48 shows the first stage of abstraction from figure 45. Predator and prey have been replaced by red and blue. Otherwise, the model is the same. Figure 48 can be rearranged, effectively by taking part of the lower loop and twisting it up and to the right. This exercise has been executed in figure 49, ignoring for the moment the dotted lines. This process of twisting into the shape of figure 49 has two purposes: first, it allows us, should we wish, to generate a chain of links, adding on, say, yellow and green at left and right of red and blue respectively: second, it creates space for the dotted lines, marked nurture.

Up until this point, the model has been simply red in tooth and claw — it has represented the simple savagery of nature. However, birds and mammals in particular protect and teach their offspring how to survive and feed. This nurture element is shown in figure 49 as enabling inherited variety, some of which may be initially less than fit, to reach a state where it can propagate by being nurtured and protected. This reconfiguration of the model is an essential step in its development, and will allow us to explore social evolution as well as Darwinian evolution.

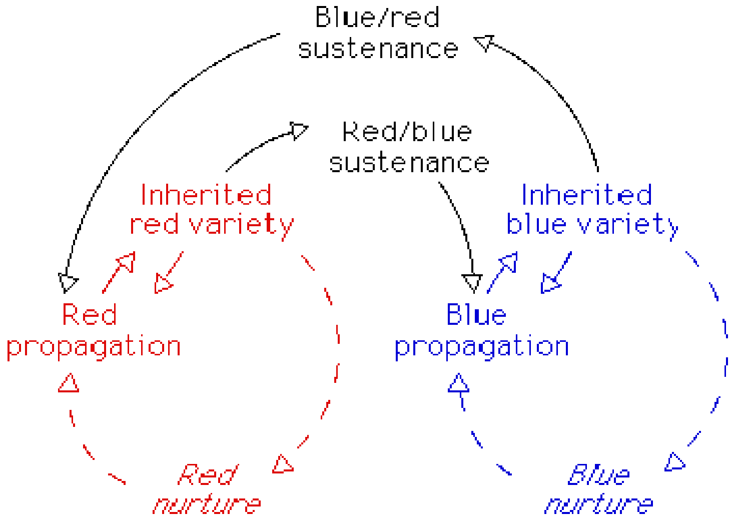
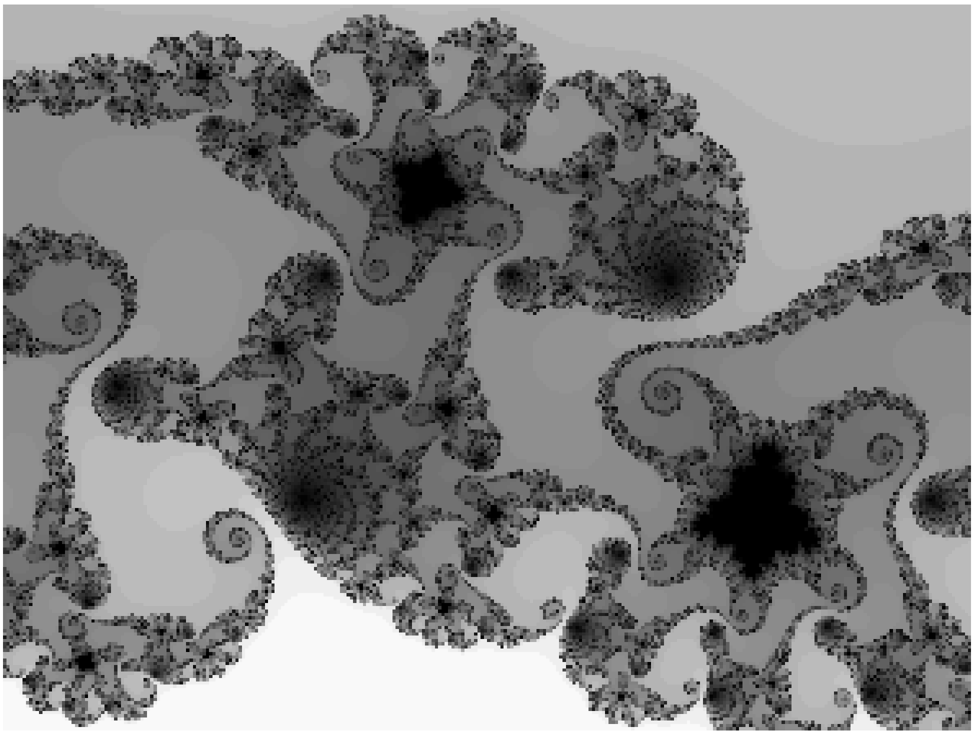


Figure 49: By twisting figure 48’s model, room is made both to extend the chain sideways and to add a nurture loop to the nature chain.

To go any further along this path requires that we explore the nurture loop. While nurture may seem apparent at the level of individuals, clearly nurture has an effect on the behaviour of groups, and is related to group identity and culture. These factors will be explored next.



Fractal 6: Filigree

The social genotype

> “Egypt's might is tumbled down, down-a-down the deeps of thought
> Greece is fallen and Troy town, glorious Rome has lost her throne
> Venice’ pride is nought.”
> — Mary Coleridge, 1861-1907

Identity, individuality, pattern, culture

Consider a human. The human infant has size, shape, and is comprised of organs, fluids, etc... As an adult, many years later, each of the organs may still be in place, but their substance has been largely replaced. Our cells have a life after which they are either replaced or, like brain cells, they simply die and waste. So, in some senses, the adult is not the same as the infant. What has not changed? Genetically, we are identical, that is each replacement cell has the same DNA as its precursor.

We would also recognize the person as being the same person, grown up — again, the identity has not changed even though physical size and appearance may have changed quite markedly.

What maintains this individuality? We are what we eat. Our many and varied interacting internal systems grow and stabilize only if they receive a constant supply of varied food (low entropy?) with which to build and replace defective or wasted parts. The replacement is constructed using an individual pattern. Only in this way can complex-variety systems sustain their identity and, as it were, stay the hand of generally-increasing entropy. As it is for the individual, so it is for an organization.

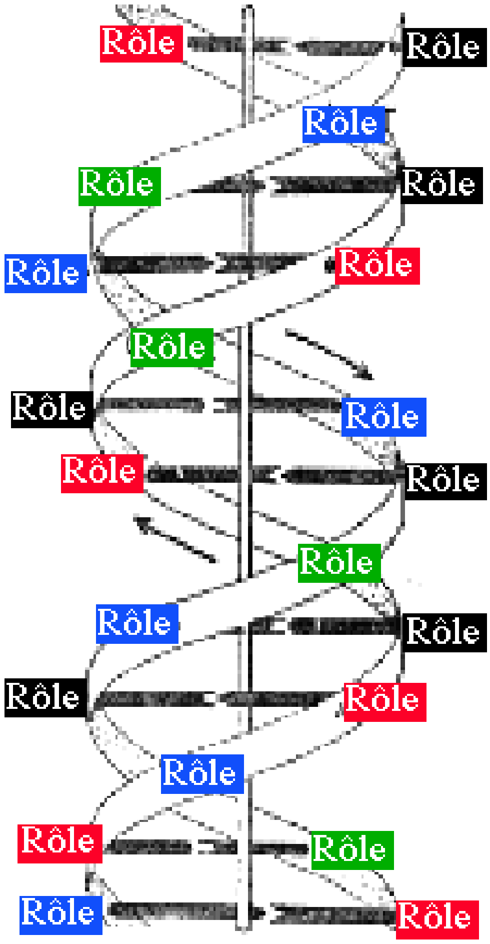
A company, association, or society, is comprised of people. Over a period of, say, thirty years, people come and go, so that there may eventually be none of the original people left; but the company retains its identity if patterns of behaviour, culture if you will, have been passed on from generation to generation. New staff with new skills compensate for staff leaving and skills wasting with time; new staff learn the ways of the existing staff, so maintaining the culture, or identity.

Biologists have names for some of these identity features:

> "The information that is encoded in the structure of the DNA molecules is known as the genotype, and has to be expressed as the observed characteristics of the cell or organism, the phenotype."
> — Cambridge encyclopaedia of life sciences

> "Phenotype is a set of characteristics determined both by heredity and environment.”
> — Penguin Concise English Dictionary

Social genotype — The concept



Rôles and stereotypes

Complex organisms, then, develop from the discrete patterns in their DNA. We also know that social groups develop patterns of behaviour which survive changes of individuals in the groups. How does this continuity develop? We all carry about in our brains the ability to adopt, and play out, rôles. For instance, we behave quite differently when dealing with our own children than with those of our friends. We adopt a different rôle as a member of a working party than as chairman of a committee, or as a student compared with a teacher. These various rôles are carried around like spare templates in our brains, to be trotted out as the occasion demands. Have you ever gone to a reunion and met people that you have not seen for many years? Did you notice how the original relationships you had with old colleagues and mentors immediately reasserted themselves?

Figure 50: The concept of a social genotype

We learn these rôles swiftly, sometimes painfully. At school, we learn to appease the school bully by behaving in a particular manner and, by so doing, lock ourselves into a pattern of behaviour from which we may be unable to escape. Children, and indeed battered wives, often accept bullying, appearing transfixed like a rabbit by a snake, when they could fight back, run, or seek assistance. When we take up our first job, there is often a period of initiation, perhaps official, but often unofficial. We might be sent for a "long wait", or asked to fetch a tin of tartan paint, or a left-handed screwdriver… the list is endless.

New members are inducted into any organization perhaps via some official education or indoctrination process, but definitely through an informal process which we describe as "learning the ropes", or "settling in". We learn how to behave towards those around us, we learn what is expected of us, and because we humans are above all adaptable, we learn quickly. In short, we learn to fit in, and in so-doing we inherit and adopt the rôles and relationships which go with the position which, although new to us, may have existed for some time. Typically, a settling-in period may take as much as six months. Here, then, is a basis of social inheritance.

There is, in all this, a phenomenon that I call the social genotype, and it is so like the biological genotype that one might begin to consider whether it is more than just an analogy, and perhaps even an extension of the biological genotype.

Rôles and relationships

Unlike DNA, where nucleotides and molecular bonds are the building blocks, the social genotype is made up from rôles and relationships. See figure 50. Each rôle is a place holder, with position, status, rules of behaviour and relationships which bind it to other rôles in a social structure. New members adopt their rôle, or face rejection — immune response. If we imagine a company, a particular rôle might have some purpose or function related to the company's business. As the chain of rôles and relationships curls up into the organization, individual rôles find themselves juxtaposed with functionally-unrelated rôles.

The complete structure of rôles and relationships develops slowly from its start. The rôles are not established alone. For a rôle to develop, it depends on relationships, and vice versa. Relationships develop rôles, rôles develop relationships. After a period of evolution and adaptation the rôles and relationships settle to a pattern, and the whole structure develops a tight web of interactions that resist change, that transcends the replacement of individuals, that exhibits immune response to rapid change, to people who do not "fit". New employees are selected only if their interviewers see them as "fitting in", so ensuring the geno-typology is maintained. The social genotype is established.

For example, two adjacent offices might contain people who are performing quite separate functions. The individuals might, nonetheless, form a bond which also becomes part of the social genotype. This is cross-bonding. Imagine now how one might try to manage change within that company. Every rôle, every relationship, every cross-bond has to be changed in some degree. Suppose a company comprises 1000 employees each, on average, having 7 functional relationships and five cross-bonds. Each employee has a rôle which gives them self-identity, status, position, self-esteem — let us say 5 parameters, each vitally important to the rôle holder. Just working numerically, and with no regard to human emotions and behaviour, we have some 175,000 parameters to consider. Is it any wonder that attempts to change organizations often fail or, when they succeed, take a very long time (typically 7 - 25 years) to have their full effect?

As we explore the notion of a social genotype, it offers explanation for culture, identity, change resistance, and it applies to organizations, families, ethnic groups, religions, societies. The social genotype is inherited, transcends individuals, evolves slowly over time and exhibits immune response.

Social/organizational "genotypes"

Once the idea of a social genotype is appreciated, it offers a new perspective through which to view familiar, perhaps over-familiar, things. Not only companies, but churches and even social beehives have characteristics which are inherited over successive generations and imply a social genotype.

Consider, for example, Christian churches. If you were to walk into a church you would find the pattern of the service little changed from that which was set in the 325 A.D. at the Council of Nicaea in Western Asia Minor under the Roman Emperor Constantine. It is from this time that we have the Nicene Creed, the sequence of collects and prayers, even rules for standing and sitting during church services, etc. (Romer, 1988.)

Or, consider the ethos which exists within large companies such as IBM, where it is reputed that, at one time, employees joined in daily prayers, and were expected to wear dark suits and sober ties. Here was the creation of a social genotype which, perhaps even today, is resisting change. Could it be that IBM’s present business problems are founded in the genotypical resistance to change which has seen other companies take the market from IBM, while it stuck to its large corporate processor heritage?

Transcendental genotypes

As the example from the church suggested, not only may we identify a Social Genotype, but there appears to be a genotype in transcendental systems too. Since transcendental systems are part of the innermost thoughts of people, they are worth exploring further. The Ancient Egyptians maintained a concept of deities — Osiris, Isis, Horus, Seth, Toth, Amun-Ra and many more — over a period from 4500BC to about the time of Christ — over twice the duration of Christianity to date. During that time the concepts and the mythology were kept alive, with a belief in life after death based on how well one behaved in life. The priests changed, the people changed, but the transcendental system lived on, providing answers to age-old questions about life and the hereafter. Over the millennia, the representations of some deities evolved, from wholly animal to human bodied but with animal heads. The basic pattern of beliefs, perhaps the equivalent to a genotype, remained broadly constant, while the representations on the artefacts and tombs evolved but with clearly inherited characteristics.

“Is it stretching the parallel too far to look upon these as some kind of phenotype?”

Figure 51: Hathor, Wife of Horus, goddess of festivity, dance and love. Lady of the West (necropolis). Worshipped from 5th Dynasty (c.2560-2450 B.C.). Later identified with Venus and Aphrodite. At left a Hathorian Column. At right, Hathor in a conventional painting, showing her horns — she was identified with the cow.

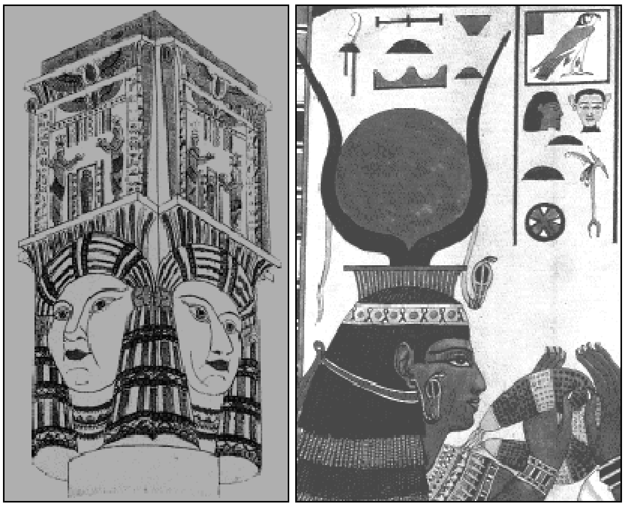


Figure 51 shows Hathor ("Castle of Horus"), who was a principal goddess in the Ancient Egyptian culture. The Ancient Egyptians had a wide diversity of gods, but there was a strict sense to their makeup. While there were gods for most natural and intangible things, there were few overlaps. The many nomes (counties) within Ancient Egypt tended at various times to propagate their own versions of the various gods, each tending to have its own Enniad, or nine-god pantheon. Each nome felt that its Enniad exemplified the true and original set of gods, and there seemed to be a spirit of competition, although the different sets of gods were all drawn from the same master set, as it were. Cults developed. There were cults of Osiris and of Hathor/Isis (the two goddesses fused into one eventually), both of which lasted long after Ancient Egypt crumbled, in Syria and Rome particularly.

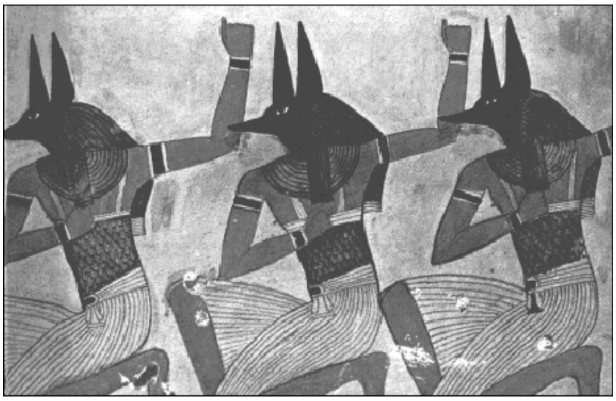


Figure 52: Martial dance of three Anubis', from the tomb of Inherka, Rameses III

Some of the beliefs were, to our eyes, arcane. Anubis, with the head of a dog, figure 52, was the god of funerary rites. It was he who supervised the winding of tapes on to the mummy. In life, a Pharaoh was identified with Horus, God of the Air and son of Osiris. In death, the Pharaoh became Osiris, God of Afterlife, and Pharaoh's son took over as Horus, so preserving transcendental, as well as royal, succession. During the transmogrification from Horus to Osiris, the Pharaoh also took on the form of other gods, including that of Anubis.

Reinforcing the transcendental genotype

Despite these, to us, bizarre beliefs, the gods of Ancient Egypt survived for a very long time. Why? What was it really that did not change? What resisted change, and why?

In searching out the answers to these seeming-enigmas, I came across examples that point the way. Consider the example of Bes, the ugly, dwarf-god of labour. Bes was shown to women in labour; because the god was so ugly, it was believed, his appearance would induce the onset of childbirth and would make the mother quickly forget the pain. Sure enough, almost without exception, it worked and the baby was born. In other words, belief in the god was reasonable, because it worked. Similarly, belief in the god of the Nile (Osiris) was justifiable; was there not a life-giving flood of the Nile each year? Other gods explained creation, the air, the earth and, of course Re, the Sun, giver of all life.

The ancient beliefs were believable, because they worked. They provided an explanation of everyday phenomena. No single god explained everything; instead a pantheon was necessary, and together the capabilities of a set of gods locked together to provide an explanation of the world. Each god had a rôle, each god had a relationship to the other gods — the pantheon was a self-reinforcing transcendental genotype.

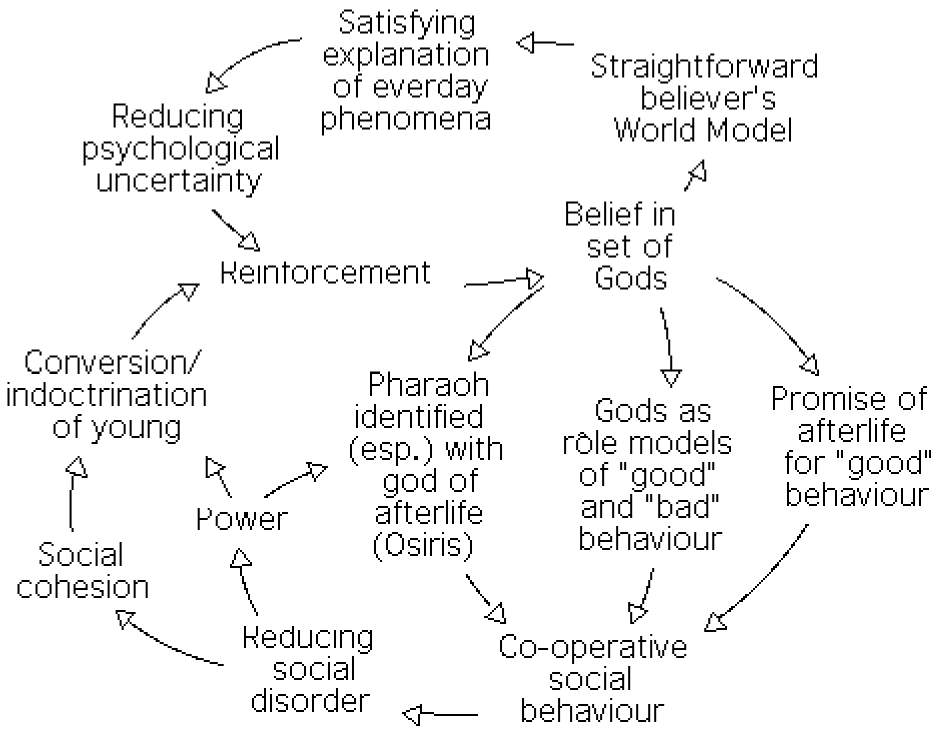

Satisfying explanation of everday phenomena
Straightforward believer's World Model
Reducing psychological uncertainty
Belief in set of Gods
Reinforcement
Conversion/ indoctrination of young
Pharaoh identified (esp.) with god of afterlife (Osiris)
Gods as rôle models of "good" and "bad" behaviour
Promise of afterlife for "good" behaviour
Power
Social cohesion
Reducing social disorder
Co-operative social behaviour

Figure 53 shows how the transcendental genotype created and sustained itself. Together, the various gods provided a basis for a belief system, which provided the people with a simple model by which to understand the world around them. Using this world model, they could explain happenings, disasters, successes and failures. It reduced their psychological uncertainty, gave a crutch of faith and, since the gods that worked survived, the beliefs were self reinforcing.

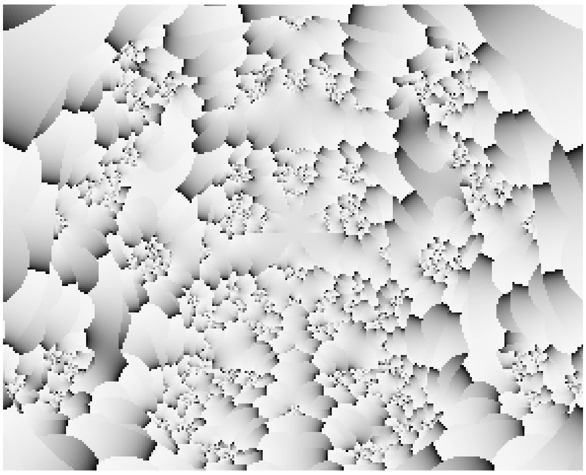
The sophisticated belief system of the ancient Egyptians propagated three main features:

- Rôle models of good and bad behaviour, contained in the myths and legends of the principal gods, Osiris, his evil brother Seth, Isis, the good wife and mother, Horus the dutiful son, and so on...

- Promise of afterlife for "good" behaviour in life For the first time, afterlife is for everyone, gods are for common people as well as for the ruler. By behaving well, according to the rôle model, one had hope of eternal life with Osiris in the Underworld.
- The Pharaoh as the ruler of both the temporal and spiritual worlds.

This last bullet presented a rather clever "double whammy"; if one did not obey the Pharaoh in life then, on the day of judgement, one would find oneself facing that Pharaoh, now in the form of Osiris in the final court.

Figure 53 also shows how these beliefs supported the establishment of a stable society by encouraging social behaviour, enabling time for the growth of social power groups (the priesthood), who also developed systems for indoctrinating new devotees into the ways and views of the belief system.



Fractal 7: The Bearskin – decomposition.

Beliefs and behaviours

> “If a man does not keep pace with his companions, perhaps it is because he hears a different drummer. Let him step to the music he hears, however measured or far away.”
> — Henry David Thoreau, 1817-1862

Belief systems and behaviour

> “I hate the indifferent. I believe that living means taking sides. Those who really live cannot help being a citizen and a partisan. Indifference and apathy are parasitism, perversion, not life. That is why I hate the indifferent.
>
> The indifference is the deadweight of history. The indifference operates with great power on history. The indifference operates passively, but it operates. It is fate, that which cannot be counted on. It twists programs and ruins the best-conceived plans. It is the raw material that ruins intelligence. That what happens, the evil that weighs upon all, happens because the human mass abdicates to their will; allows laws to be promulgated that only the revolt could nullify, and leaves men that only a mutiny will be able to overthrow to achieve the power. The mass ignores because it is careless and then it seems like it is the product of fate that runs over everything and everyone: the one who consents as well as the one who dissents; the one who knew as well as the one who didn’t know; the active as well as the indifferent. Some whimper piously,

> others curse obscenely, but nobody, or very few ask themselves: If I had tried to impose my will, would this have happened?
>
> I also hate the indifferent because of that: because their whimpering of eternally innocent ones annoys me. I make each one liable: how they have tackled with the task that life has given and gives them every day, what have they done, and especially, what they have not done. And I feel I have the right to be inexorable and not squander my compassion, of not sharing my tears with them.
>
> I am a partisan, I am alive, I feel the pulse of the activity of the future city that those on my side are building is alive in their conscience. And in it, the social chain does not rest on a few; nothing of what happens in it is a matter of luck, nor the product of fate, but the intelligent work of the citizens. Nobody in it is looking from the window of the sacrifice and the drain of a few. Alive, I am a partisan. That is why I hate the ones that don't take sides, I hate the indifferent."
> — Antonio Gramsci

The ancient Egyptian example is a low-sensitivity example of extremely powerful influences continually reinforcing an endemic cultural pattern or identity. There are many parallels today — ethnic, quasi-religious, social and organizational. Do present-day social genotypes lock-in as hard as that of ancient Egypt? If so, then is it practicable, advisable, or even feasible to force rapid change on a system formed around a genotype? Or, will results lead to some form of breakdown of order? To explore these ideas, the transcendental genotype of ancient Egypt has been updated to a modern-day equivalent, figure 54.

Figure 54: The Establishment and maintenance of a belief system.

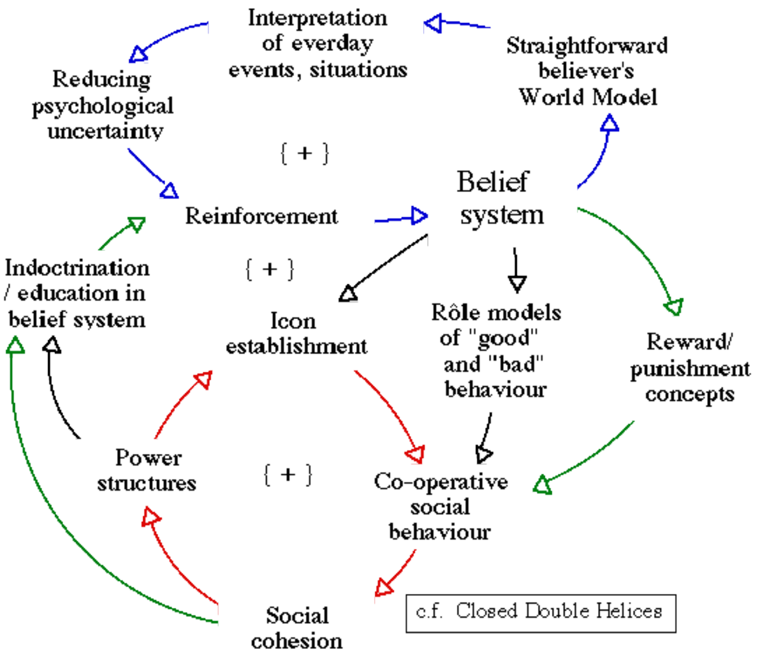

Interpretation of everday events, situations
Straightforward believer's World Model
Reducing psychological uncertainty
{ + }
Belief system
Reinforcement
{ + }
Indoctrination / education in belief system
Icon establishment
Rôle models of "good" and "bad" behaviour
Reward/ punishment concepts
Power structures
{ + }
Co-operative social behaviour
Social cohesion
c.f. Closed Double Helices

Figure 54 is directly-analogous to Figure 53. There is a belief system which, as before, provides explanations of everyday events, and which reduces psychological uncertainty. For many of us, it may not be based on any religion, but it must give satisfaction to self reinforce.

This upper loop is about us as individuals — we may share a belief system with others, but we need not, and we may not know if we share the same beliefs and values as others around us.

Our belief system generates three categories of concepts:

- Rôle models of "good" and "bad" behaviour, where our perception of good and bad may be very personal, and may even change with context. A member of a New York gang may believe in something as good in the context of gang membership which he may believe, with his local priest, is bad in the context of the church, e.g. killing.
- Punishment and reward concepts. People who have "done wrong" will accept, even expect, punishment according to a set of personal rules. People who have done something they believe is good will, equally, expect particular kinds of reward.
- Icons — we have already mentioned IBM, and the three letters are an icon. Leaders become icons, as was the Pharaoh. Eisenhower, Montgomery, Rommel, Schwartzkopf — all became icons in their time, representatives of an ideal. Icons form rallying points or provide shorthand representations of a belief system. In the UK, our Royal family is an icon, representing the British way of life.

Figure 54 shows clearly the three principal loops forming the closed double helix. In pursuing this notion of the enduring belief system and the social genotype, we have identified a model which, in shape at least, is similar to that of figures 48-49. Let us summarize. The belief system, which permeates the social/transcendental genotype, is expressed and established by three interacting chains:

- A chain reducing uncertainty, worry, fear of the unknown, in the minds of individuals.
- A chain evolving social order and power structures over time.
- A chain reinforcing "good" behaviour.

These chains are redolent of the food chain and inheritance chain interactions.

Locking to a genotype — Immune response

The concept of the social genotype proposes why organizational and social systems resist change, but are able to adapt and evolve slowly. This section examines the same issue but from a different angle, using as an example resistance to change in the defence industry, topical at the time of writing.

Figure 55 shows the general scheme, highlighted by Peter Senge, 1991. in his seminal book, The Fifth Discipline. I have modified his approach only a little. At the left of the figure is the hoped-for outcome from innovation, sometimes referred to as "the virtuous circle". Innovation and creativity are expected to improve defence business performance in a declining market, so improving the prospects for company survival, enabling further improvements, moves away from dependence on defence contracts, and so on. Unfortunately, the changes create a reaction within the organization, by threatening the status quo. This evidences itself through dedication to the current hierarchy, with its established way of doing business, and its existing tools and methods. All of this resistance to change prejudices any continued innovation. In effect, any thing new is treated as "Not invented here", and given the cold shoulder. I call this the immune response.

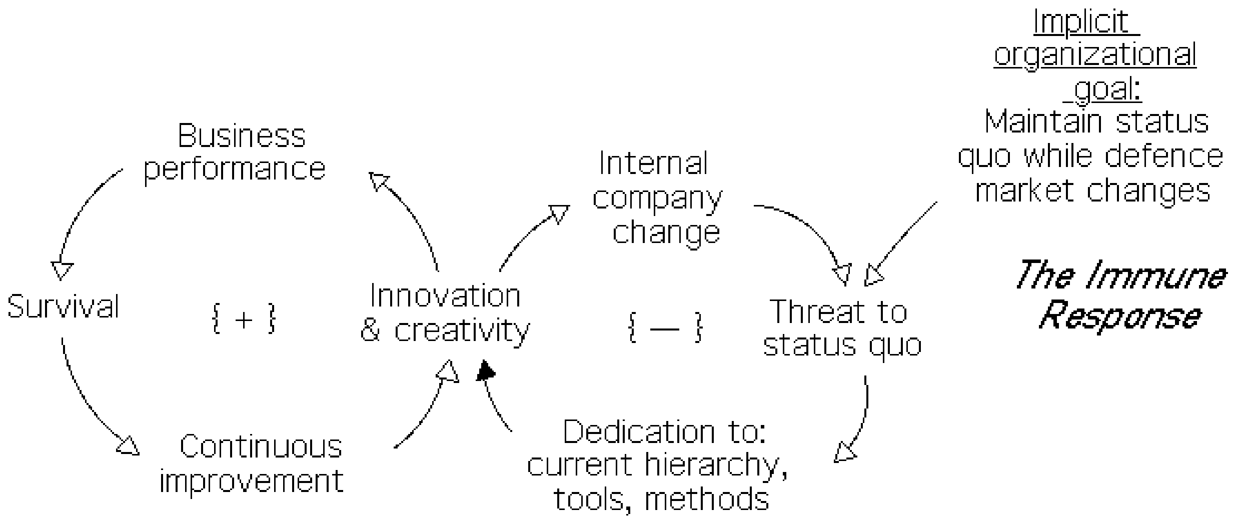


Figure 55: Immune response within a defence company. The filled-in arrowhead signifies an inverse relationship; open arrowheads signify positive relationships.

At its most extreme, it results in new members of staff being isolated and ejected from the company, new tools being rejected even though they may be just what the company needs to improve performance. It also presents itself, more subtly, as an apparent acquiescence to new ideas such as major re-organizations, but with no effective change. Typically, middle and senior management may introduce an initiative that affects those below them, but does not affect their own rôle and status. Not surprisingly, the initiative founders, and management blames intransigence or non-co-operation amongst the work-force. As figure 55 shows, there is a de facto-implicit organizational goal of maintaining the status quo.

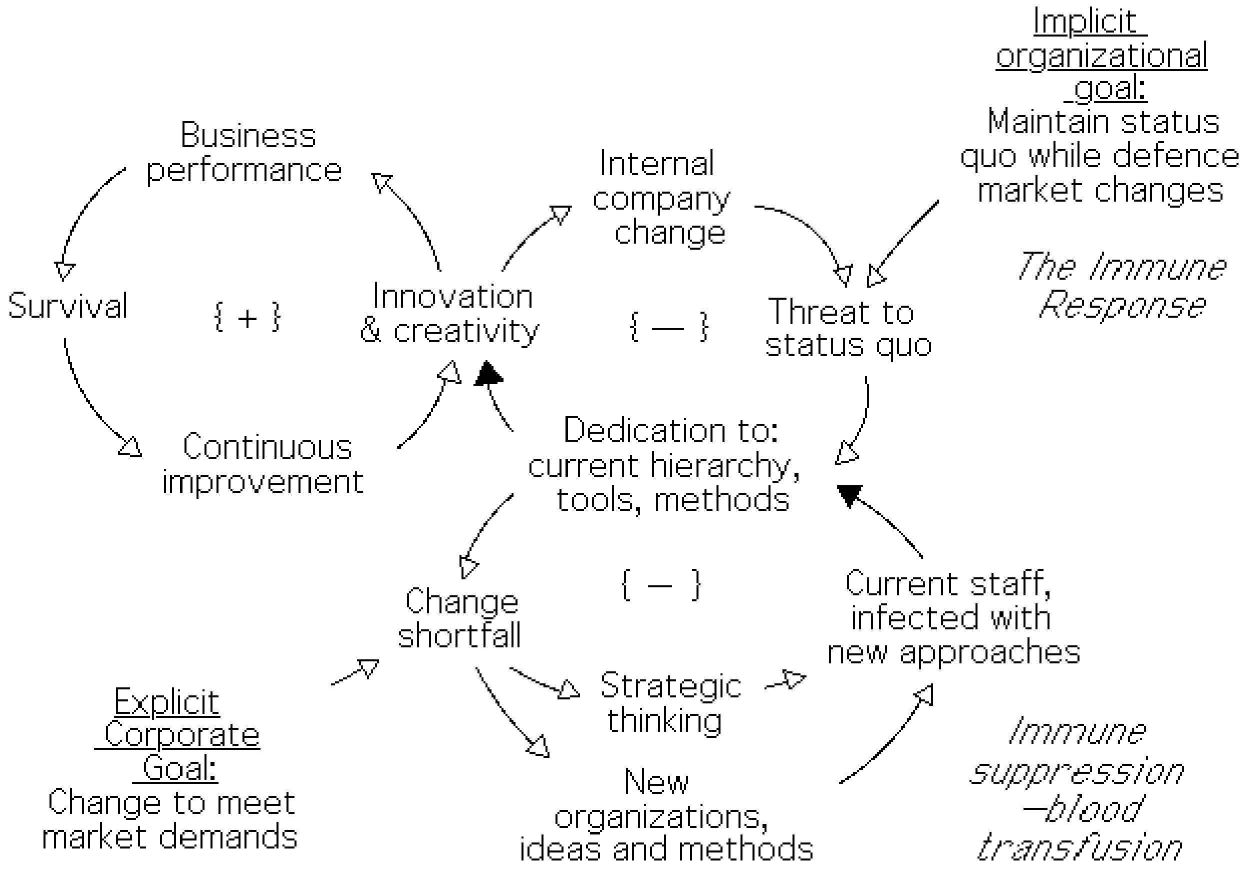

Implicit organizational goal:
Maintain status quo while defence market changes
The Immune Response
Business performance
Internal company change
Survival
{ + }
Innovation & creativity
{ — }
Threat to status quo
Continuous improvement
Dedication to: current hierarchy, tools, methods
Change shortfall
{ — }
Current staff, infected with new approaches
Explicit Corporate Goal:
Change to meet market demands
Strategic thinking
New organizations, ideas and methods
Immune suppression —blood transfusion

Figure 56: Immune suppression.

Immune suppression

Figure 56 continues the medical analogy, by suggesting that immune suppression may be possible. If there is an explicit corporate goal of change, then that goal might be achieved by infecting the workforce with new ideas, methods and with strategic thoughts. Such thoughts would include, perhaps, the propagation of a shared vision of the organization's future — an appeal to the belief systems of those resisting change. If their beliefs and values can be modified, then change may be welcomed, rather than resisted. Figure 56 falls short of explaining how the process might work in practice, e.g. how long it might take. Evidence to date suggests that these are very uncertain parameters, much depending on the charisma and leadership of the company.

The recurring theme

A closer look at figure 56 reveals that:

- The model is yet another closed double helix.

- The model represents a contest between belief systems — those of the organization’s employees and the corporate, or employers’, belief system.

The recurrence of these two themes is remarkable, and suggests a consistent, underlying pattern in evolved systems, which may help to unravel the most complex of issues.

Ideologies

Is there some connection between rôles and beliefs? It seems likely that both may be generated, at least in part, by ideology. Ideologies, our innermost view of "how things are, or ought to be", give us perceptions of the "appropriateness" of rôles. Ideologies provide foundations for the beliefs through which we view and judge the world around us. So, when promoted to the status of manager, we may feel that it is our place to take charge, to give the orders, to be the leader, and we may set about fulfilling that rôle, even although it might be out of character. Our ideology about management has generated beliefs about the rôle we must adopt. In adopting, and acting out (for it is acting) that rôle, we satisfy the expectations of those around us, we gain satisfaction and rôle reinforcement from their acceptance of our new behaviour, and the social genotype reinforces itself. Should we, instead, behave in an unorthodox manner as a result, perhaps, of studying some modern management methods, those around us may react unfavourably, and we will either give up our unorthodox ways or face hostility and rejection.

As we have seen, belief systems need bear little or no relationship to reality, just so long as they work for the believer. Ideologies seem to run even deeper, providing each of us with a fundamental prescriptive model. So, when challenged that she is scrounging off the state, a teenage unmarried mother living on state benefit in a council flat announces (and believes) that she is entitled, because her parents paid income tax and national insurance all their lives. This is simply the payback, she states.

Ideologies are at their most obvious in the political arena. Whenever a politician stands up and announces: "In my opinion...", you may be sure that the following statement is based on ideology since, if he or she had worked the answer out rationally, they would not have to resort to opinion! The most obvious ideologies are between left and right. Both ideologies would claim that theirs is the only sensible way to make the nation prosper. Each is convinced. Neither is prepared to consider that government of highly-complex, dynamically-changing situations using fixed, outdated and/or simplistic ideologies is really rather unlikely to be effective.

Why this adherence to highly questionable ideologies? It may be part of our evolutionary heritage. We evolved through recognizing and reacting to danger instantly, otherwise we would not have survived as a species. We evolved by characterizing situations, by stereotyping people, by assessing rapidly. To do this, each of us carries around a store of characterizations, of stereotypes, and it is virtually impossible for us not to use them. People boast, for instance, of their ability to sum up another person within 5 seconds or 5 minutes of meeting them, but should, perhaps, be more proud of taking their time. Teenagers at a disco sum up members of the opposite sex in rather less time, simply on the basis of appearance, either of person or dress. Social evolution provides us with more sophisticated mental models, ideologies, but with the same purpose of enabling rapid assessment of new situations, people or information.

Consider the current ideology in the western economies concerning competition. In Nature (so politicians may argue), competition results in survival of the fittest, the weak go to the wall. All that politicians need to do, then, is to create an environment where competition abounds, sit back and wait for strong economies to emerge. The inconvenient parts of the analogy between economies and ecologies are not mentioned. For instance:

- Natural evolution takes a very, very long time, employing countless mutually-independent reproductions and generations.
- Natural evolution absorbs an enormous amount of energy to weed out weak predators and prey.
- Natural evolution depends for its stability on a large array of interacting species, large and small, predator and prey, fauna and flora.
- Natural evolution develops symbiosis and synergy between species, to their mutual advantage, provided there is a sound and effective infrastructure — the biosphere — to support the interactions.
- Ecologies are highly susceptible to the introduction of alien species from other ecologies, which may decimate them if there is no "ecological antibody".

An examination of the various capitalist governments of the world shows that "free market competition" is interpreted in many different ways. De facto, there seems to be very little genuinely-free competition at international level. But then, no ideology has to relate to the real world, just so long as it works…

Belief system model

Belief systems are at the core of resistance to change; they may be thought of as forming the bonds within the social genotype.

Where is the "system" in belief system? Figure 57 illustrates one viewpoint:

- The system is a set of mutually consistent beliefs which, together, provide a consistent view or explanation of the world to their advocates.

- Completeness of the set is essential to reduce entropy in a believer’s mind.
- The mutually consistent set may be generated by an ideology, and emerge as a theology, a political dogma, or some perceived self-evident "truth". Ideologies need not bear significant relation to any real world.
- Beliefs generated by ideologies need not be "correct," so long as they comfort the believer, provide satisfactory explanations of everyday events, reducing uncertainty.
- Ideologies may propagate rôle models of "good," "proper," or "bad/improper" behaviour. These, too, need not be "correct" in any rational sense.

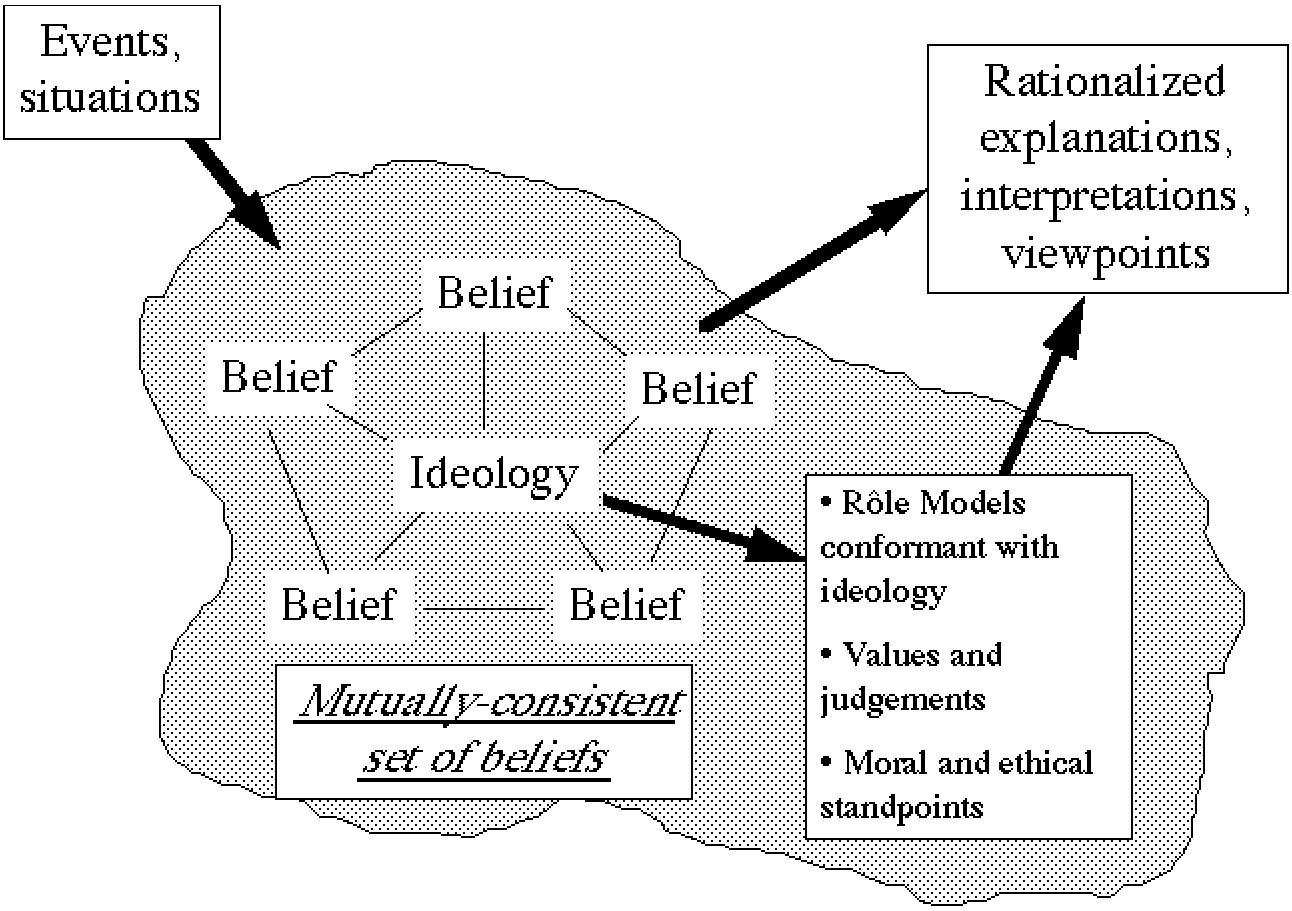

Events, situations
Rationalized explanations, interpretations, viewpoints
Belief
Belief
Belief
Ideology
Belief
Belief
Mutually-consistent set of beliefs
• Rôle Models conformant with ideology
• Values and judgements
• Moral and ethical standpoints

Figure 57: Ideology, beliefs and rôles.

Developing the belief system model

Figure 58 brings the strands of modelling together. At the left is one link of the nature/nurture model from figure 49. At the right is a simplification of figure 54, the establishment of a belief system. The similarity between the two is striking. In much the same way that natural species compete and prey on each other, so can belief systems, the seat of second natures.

The general form of the model already presented for prey-predator relationships may, with care, be applied to competing belief systems.

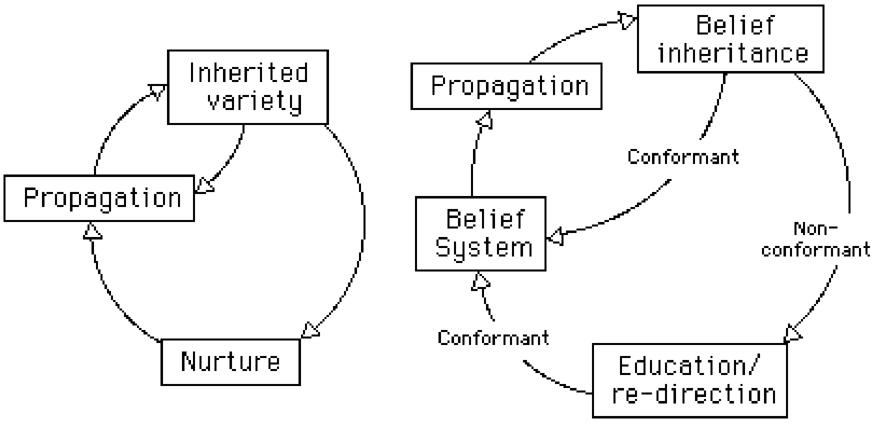


Figure 58: Comparing the nature/nurture model and the belief system model.

The belief system battle

Figure 54 outlined a model of the development and sustainment of a belief system. It is possible to simulate that model, using one of the several system dynamics modelling packages available on the market. However, more interesting is to simulate two competing belief systems under various conditions, and to explore such ideas as:

- How rapidly can a new belief system capture followers from an established, but moribund, belief system — what might the rates of switching allegiance be?
- How far can an ailing belief system, under siege from new, or anarchistic ideas, be propped up by increasing the social investment in education, in seeking out doubters and either ejecting them from the social group, punishing them or re-indoctrinating them?
- Does an ailing belief system behave differently if the social investment is steady, or can a sudden injection of investment reverse the trend of losing believers to the opposition?
- Can a belief system be unassailable?
- What is the critical mass for a belief system, below which it will not self-sustain or grow?
- ...and many, many more…

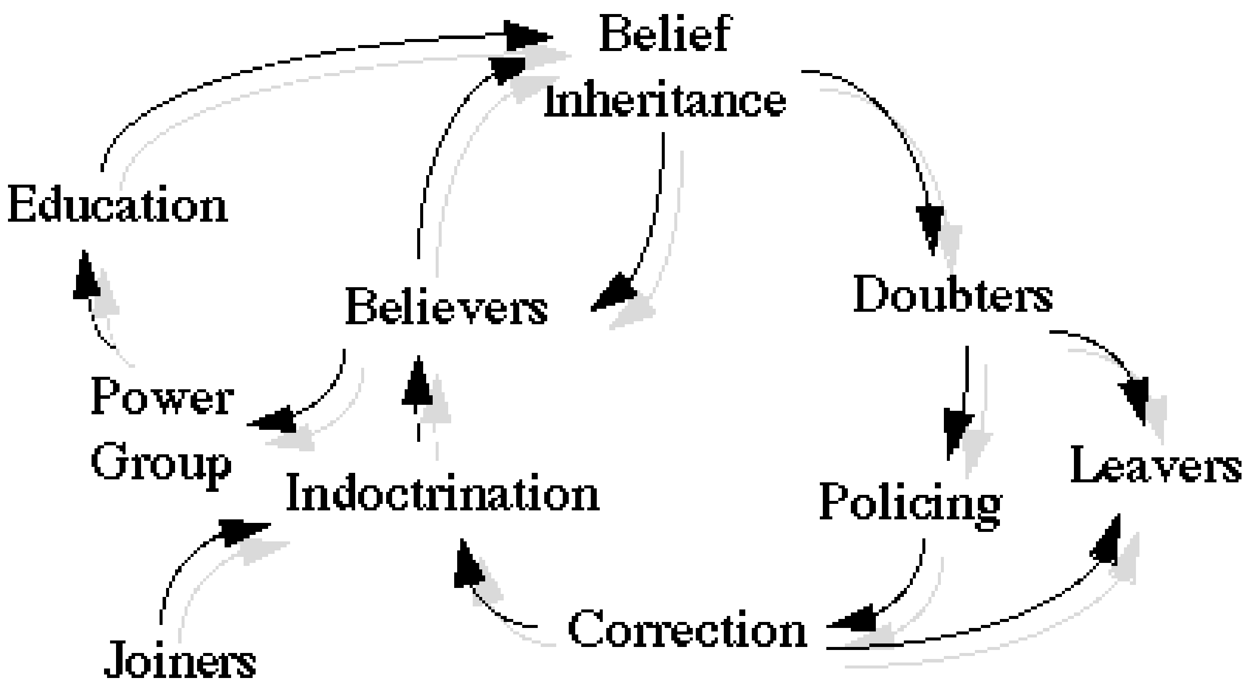


Figure 59: Model of a competing belief system.

Figure 59 shows the way the model is developed, and a full representation would show two or more such models, interlinked after the style of figures 49. For example, leavers in figure 59 go to another belief system, while joiners come from another belief system. At centre left is a number of believers, those who share in the particular belief system. Belief is passed to others who may inherit the belief in some degree — this is shown at the top of the figure, where some of the inheritors join the believers, while some are doubters. Doubters may become leavers (at right) or their doubt may be recognized (policing, a term used in a general context, does not necessarily imply a police force). If their doubt is recognized, they will enter a period of correction (not necessarily imprisonment) before being re-indoctrinated and restored to belief. Alternatively, correction may fail, and failures also become leavers. Leavers are presumed to go to the other half of the model, to the competing belief system, from where also come joiners, entering at the left through a process of indoctrination. Finally, but most importantly, believers develop power groups and organizational structures, which in turn establish, inter alia, education systems which teach the belief.

The model parameters may be interpreted and adjusted to address a variety of social structures. For example, at a national level, we could consider the shared state belief system to be founded on Judeo-Christianity, and to have been under attack from a variety of sources: science, media, youth culture, organized crime. The nation has a police force, a judiciary, and a corrective system all based on behavioural rôles and punishment concepts traceable to the old testament of the

Bible (and beyond to Ancient Egyptian beliefs of justice). Those who share the Christian belief, also share in those concepts of the way people should behave, and the punishment that should be meted out to wrong-doers. It is noteworthy in the UK, at the time of writing, that attempts are being made to bolster the somewhat ailing Christian belief system by invoking a stricter education system: national curricula are being introduced, with attempts to make Christian education compulsory in schools, as it was under the 1948 education act. There are also moves to tighten the rule of law, with stricter penalties for crime, and the police force has been increased.

> “Will the education and policing compensate for the erosion of the national belief system?”

The model is scale independent. Consider a family, perhaps an Asian family, with their own, inherited beliefs and culture, living in London. The parents seek to pass their beliefs, rules of behaviour, morals, ethics, etc., to their children. The children go to school, watch television, go to discos, and generally experience the multi-ethnic cultural melting pot of London. The family can be represented by the model of figure 59. All the elements are there. The children, if not the parents, will experience doubts. The parents may try to correct their children, may make them attend lessons in their religious centre, may punish them for perceived wrong-doing. All the time, there is a tension between the belief system within the family and those outside, as the family seeks to preserve behaviour appropriate to its inherited culture.

Some communities go further than families. The Hasidic Jews centred in Stamford Hill in North Least London, for example, have established a community which is largely isolated from those about them. The community migrated originally from eastern Europe, an even today the men wear costumes redolent of Cossacks, with riding breeches and fur headgear. The community polices itself, and can become very hostile towards a member who brings in the Metropolitan Police. The community applies its own strict laws, arranges marriages, and observes their interpretation of the Bible Old Testament rigorously. No mechanical or electrical devices may be touched on the Sabbath, even electrical switches may not be used. They have their own school, and their own teachers, and children learn the scriptures and the laws from infancy, in addition to normal lessons in mathematics and science. Nobody marries outside the community. Nobody joins the community except through birth — the birth rate is very high, a dozen children per mother not being unusual.

How does such a community react with the community around them? Can they retain their "purity"? Will their growth dilute their faith? As they grow, must they inevitably fragment, or will their education system and their punishment/reward system hold them together?

Running the model

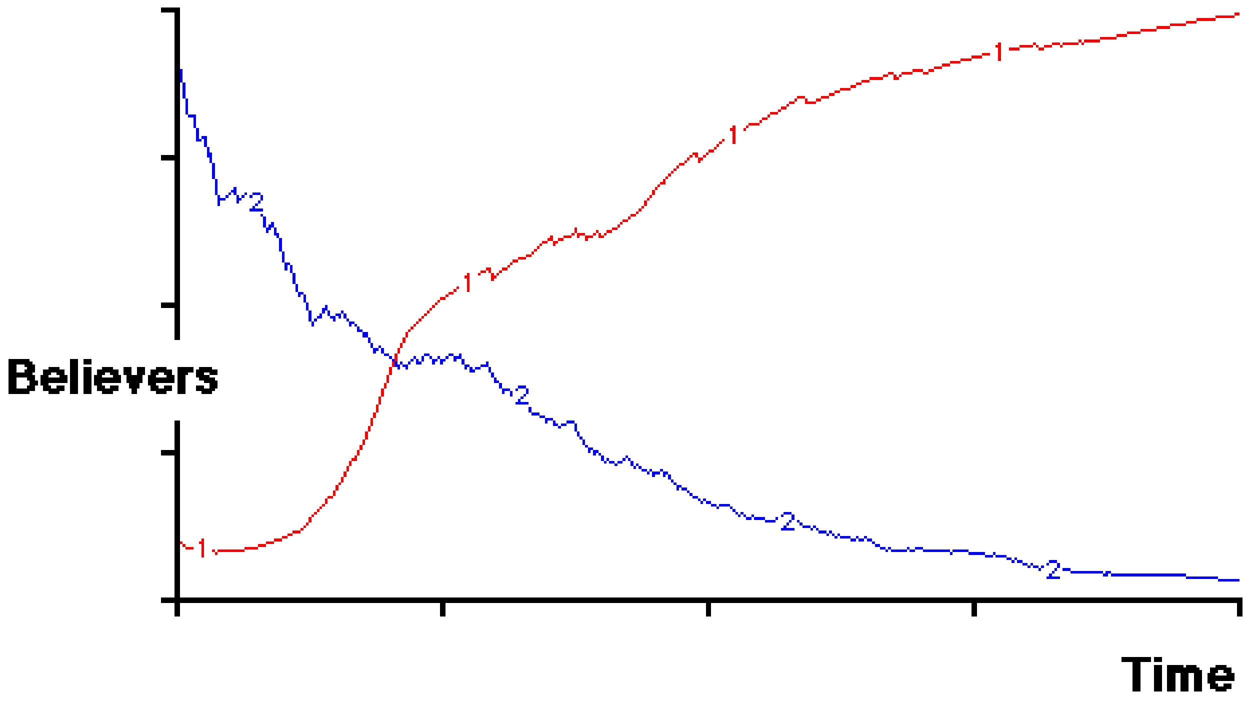


Figure 60: Competition between an ailing and a new, strong, well-supported belief system.

These and other questions are typical of the questions that we might seek to address with the aid of suitable models based on Figure 59. Figure 60 shows the results of one, rather general, model run in which the question being addressed is: "how rapidly can a new, strong belief system overrun an existing, but moribund, belief system?"

The new belief system, line numbered “1” in Figure 60, captures the available population very quickly indeed. Initially, there is a seemingly exponential growth in new believers, which the model assumes to be supported by good education, policing and correction systems. The new belief is assumed also to be appealing to potential believers - a new belief system that does not make sense, which does not explain the world in evidently reasonable terms, will never catch on, since it will jar with reality. The beliefs do not have to be objectively "true" of course, but they must make consistent sense, as did the gods of Ancient Egypt. The general shape of Figure 60 suggests an exponential loss of believers from the moribund to the new system, line numbered ‘2’. The initially rapid growth in advocates of the new belief, line 1, tails off to a plateau, as the number of believers remaining to be attracted reduces; line one adopts a sigmoid, or "S’-shape.

Figure 60 represented a simple and extreme case. Life is rarely that simple.

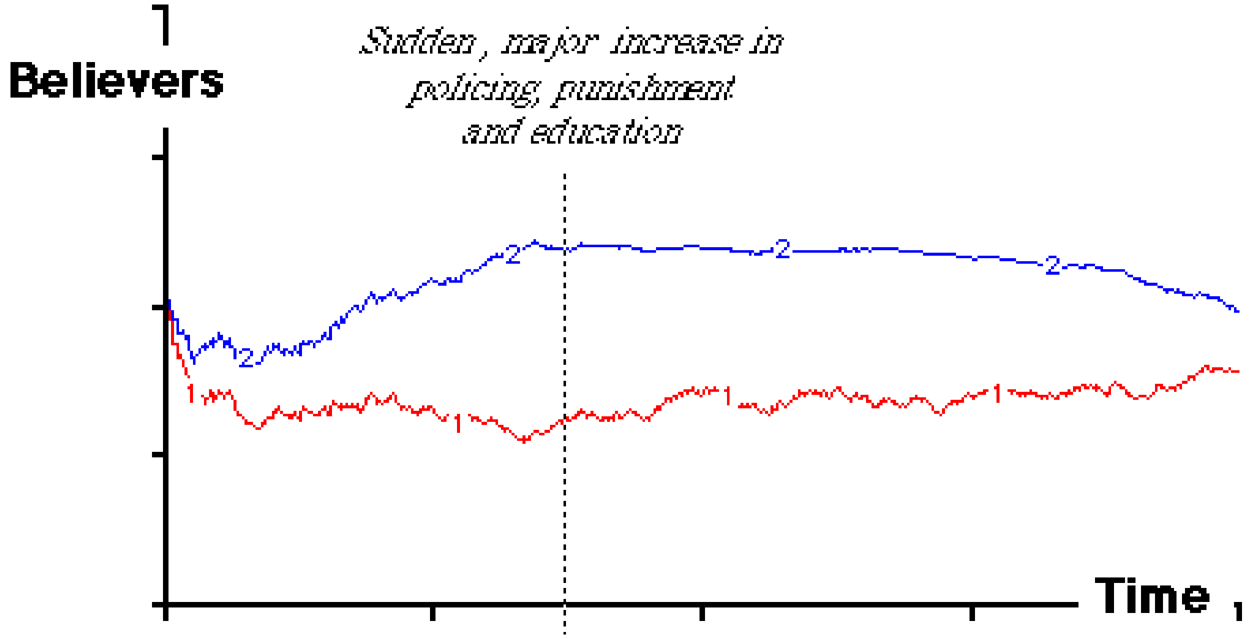


Figure 61: Model of an attempt to prop an ailing belief system.

Figure 61 represents a moribund belief system, line 1, which is being taken over by a more acceptable belief system, line 2. The newer system is making good ground, believers in the older system are falling away. The older system is the establishment, however and, at the time indicated by the vertical dotted line, that establishment decides to do something. Unable to restore their beliefs directly, they invest heavily in renewed policing, teaching and punishment practices. The impact of these measures, although applied at the same time in the model, do not take effect simultaneously.

Policing may have a fairly immediate effect, but stepping up the education takes time to put into practice, and still more time to increase the number of believers.

The model suggests that, despite the heavy investment by the establishment to restore the original situation, nothing much happens for a long time, except that the status quo is preserved.

Is it really possible to prop up an ailing belief system, or will it inevitably collapse? Running the model many times, and introducing the sudden increase in policing, punishment and education at earlier and later times suggest that it is possible to leave it too late — that once the two populations have diverged beyond some poorly defined difference, there is no recovery, only a slowing down of loss rate to the new belief. The model also suggests that a really believable belief system, one that is self-evidently valid, has a greater impact than education, policing, and punishment, separately or together. But remember — we are merely employing a computer simulation, and a broadly-based one at that. At best, it can help us to ask questions and to question answers.

Command and control

The models used above have favoured the idea that we can, in some degree, equate Darwinian evolution models with social evolution models. The parallels between the two types of model becomes even more apparent when we consider man in his primitive, aggressive rôle, particularly in warfare.

Command and control is the term used by the military to describe what we might loosely call the management of conflict. The term, command and control, came into public prominence during the Gulf War, when the allied forces declared their intention to neutralize Saddam Hussein's command and control HQ. These are the centres where the generals gather information about their enemy and about the status of their own forces, make decisions about what to do next, and then give orders to their forces. Neutralizing an enemy's command and control strikes at the central nervous system of a force, the notion goes; without command and control, the enemy forces will be unco-ordinated, in disarray, and will be easily beaten. Of course, an enemy might have the same idea, and so opposing forces may end up trying to neutralize each other's command and control HQ.

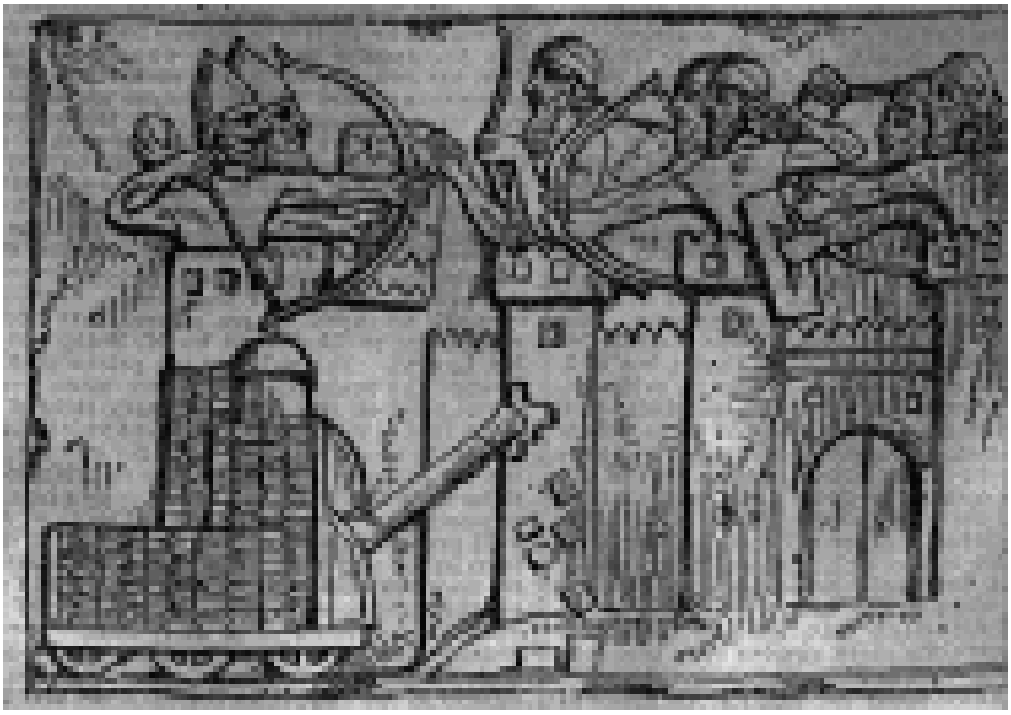


Figure 62: Assyrians besieging a City, c. 600 B.C.

Because command and control is seen as so vital to a force, it has been the subject of much analysis. Scientists and engineers have sought to understand the nature (that word again!) of command and control, and to provide technological support to the making of robust decisions.

Analysis has proved difficult, however, for three principle reasons:

- While the technology might be reasonably predictable in what it does, the humans operating it and working with each other are most definitely not predictable. In warfare, the adrenaline runs high, fear and aggressive instincts vie with training and rational thought for control of behaviour.
- Armies organize themselves, like authoritarian managements, in hierarchies, with an army comprising several divisions, each division comprising several brigades/battalions, and so on down to company level. The command and control system therefore consists of command centres within command centres within command centres… making conventional analysis difficult.
- The complex interactions between opposing forces creates a typically-chaotic situation, in which the short-term future may be difficult, even impossible, to predict.

By examining command and control in history, a technology-independent perspective may be developed. Figure 62 certainly has technology on show. The Assyrians have a splendid siege machine, with a built-in battering ram which is breaching the castle wall. Attackers and defenders are showering each other with arrows. Is it Darwinian or social evolution that determines their behaviour? Both perhaps.

Consider the commander of the besieged castle. His concerns must be with many things:

- Will the ammunition hold out?
- Will relief arrive? When?
- How can he eke out supplies?
- How can he maintain the morale of the defenders?
- How can he convince the Assyrians that the siege is futile, that they will never surrender and can hold out indefinitely?

At that time, it was not unknown for the commanders of besieged garrisons to throw food over the ramparts during a lull in the fighting. This was designed to convince the enemy that they were in for a long siege, and perhaps to convince the defenders that their leader had a trick or two up his sleeve. Perhaps the battle is not just about firing weapons, making holes in walls.

Perhaps the battle is about a struggle between belief systems. The siege commander faces two struggles:

1. The struggle to overcome the enemy commander’s will to conquer.
2. The struggle to maintain the belief of his own forces in their ability to succeed.

From this perspective, command and control is no longer just a series of nested, self-similar HQs. Instead, it may be viewed more as figure 63, which shows two opposing forces and the struggle between two Belief Systems. The commander has both to maintain the beliefs of his own force and overcome the will of the opposing commander and his force. The model is "flat", in the sense that hierarchy (although represented in the figure) is not dominant, which makes analysis very much simpler. The flat structure comes about because, in a very real sense, the beliefs must be shared at all levels if the whole force is to act as one.

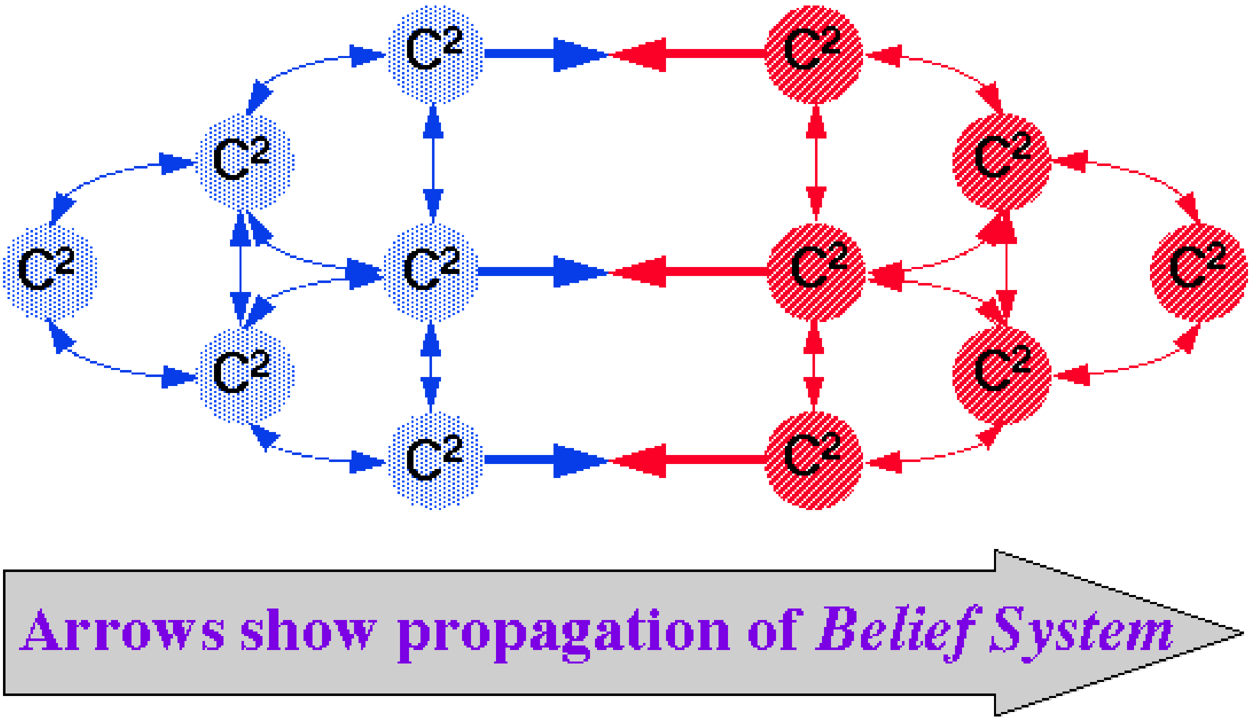
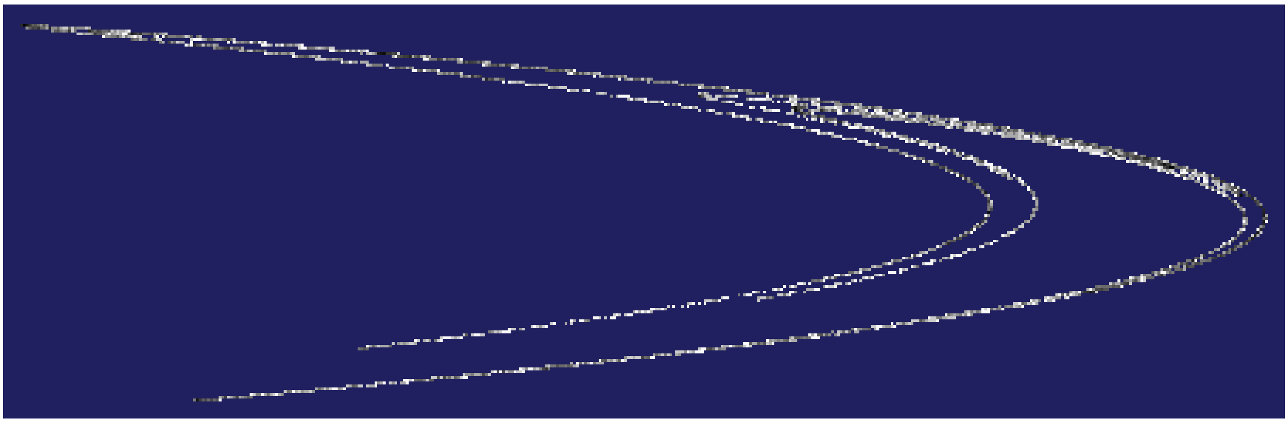


Figure 63: Command and control as a struggle between competing belief systems.

Like other belief systems, conflict between opposing armies can be analysed using the model of figures 59 as a basis. Such analysis does not invalidate other kinds of analysis, but it does seem that the modelling of belief systems is getting to the heart of the matter. Technology is important in war, but spirit, indomitable will to win, training, experience, esprit de corps, morale — these are the real core of the issue. Leave these out, and we cannot achieve a sensible result. Training is typical.

One of the objectives of military training is to make actions become "second nature” so that the individual or the group continues to perform even when frightened, hungry, injured or tired.



Fractal 8: Strange attractor

Towards a theory of complexity

Stability and chaos

> "He that will not apply new remedies must expect new evils, for time is the greatest innovator"
> — Bacon Essays, 1625

Stability is associated, conventionally, with some low energy state: open, interacting systems tend to dynamic stability with high energy operating at the edge of chaos. In part 4, the search is on for a theory of complexity, a counterpart to the theory of everything. On what would such a theory of complexity be based? It must at a minimum consider:

- The dynamics of complex systems.
- Sources and generators of complexity.
- The stability of complex, open, interacting systems.
- Models of complex behaviour.
- Laws of complex Behaviour, offering:
  - Explanations of phenomena.
  - Predictions from the laws.

Given all of these, we might have a theory of complexity which would be both useful and capable of challenge.

Dynamic systems model

Examination of open interacting systems reveals that activity levels increase with the energy available to the systems. Energy entering a set of interacting systems:

- Drives activity, or...
- Drives speciation, or...
- Both.

Activity and/or speciation increases or decreases until the rate of energy absorbed in the internal processes equals that entering the system. Put at its simplest, more energy results in more activity and/or more speciation.

What evidence is there to substantiate such a claim? For physical and chemical systems there is unlikely to be much dispute, since the behaviour of such systems is so readily observable. Heat a gas and the molecules move faster; temperature may be defined by the kinetic behaviour of a gas. Sugar dissolves faster in hot tea rather than cold water. Chemical reactions are accelerated by the addition of heat energy, from the washing of clothes and dishes, to the speeding of catalysis.

For ecologies, the evidence is similarly simple but persuasive. Growth and decay in tropical rain forests operates at up to five times faster than in moderate climates. This evidence is particularly interesting since, unlike the simpler physical and chemical examples, ecologies exhibit such behaviour while encompassing very high levels of complexity, with many interacting systems in many interwoven hierarchies.

Energy entering an open system promotes: growth; activity; interaction, including (where appropriate) reproduction and speciation; decay; and recycling. There is a marked tendency for complex systems to cycle continually.

Sources and generators of complexity

In social and economic systems, energy may be generated by powerful ideologies or by the pursuit of wealth, status, happiness, promotion, etc... The energy within such systems may be seen as the potential energy of wealth, visions, ideals, etc...

Specialisation, usually a biological notion, appears around us in many other systems:

- Product variants, e.g. car models, building designs, washing machines, food mixers, clothing fashions, perfumes and jewellery, washing powders, etc...
- Infrastructure densities, e.g. telephones, sewers, roads, railways, computer networks…

We tend not to think about speciation of material things, but their variety clearly increases with wealth and freedom or openness…

Natural and man-made environments

Fractal 9: "Chicken legs".

We are used to thinking in terms of three physical dimensions, with time being a fourth. It is simple enough to increase these numbers, and to see complex things rather more simply in the process. Conversely, things with many dimensions, N-dimensional entities, can be reduced to the familiar two or three to advantage also.

Suppose we allow dimensions to include rather more than up, sideways and forwards. Suppose we allow:

- Temperature, temperature range,
- Humidity, humidity range,
- Pressure, pressure range,
- Foods,
- Toxins,
- Predators,
- Hosts,
- Co-operators, etc., etc.

We can put these together as dimensions. So, a complex natural environment may contain a space, for a time, which has a high but stable temperature, accompanied by humidity varying between 90-100%, at high altitude/low pressure, with a range of lichen and mosses, no toxins and no predators.

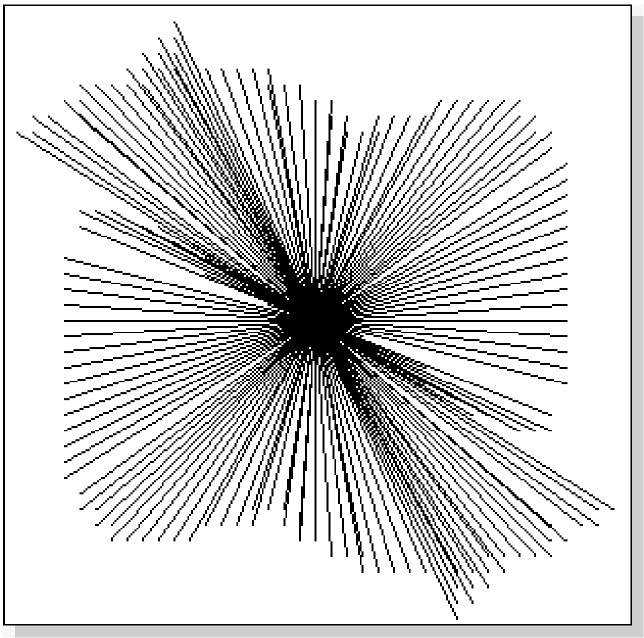
We have described a micro-environment which might offer a "niche" to a particular species which evolved to make use of it — after all, it appeared to be safe. N-dimensional spaces offer many such niches — see fractal 9; flora and fauna which evolve, perhaps chaotically, will eventually speciate to produce something which will shelter and flourish in particular niches.

It is as though the availability of a niche determines the survival of species.

How, then, do niches fill? They fill to an extent, and at a rate, determined by rates of activity and rates of speciation. The greater the "free" energy within the environment, the faster the N-dimensional environment will be filled. But it is not as simple as that; consider both Fractals 9 and 10, which try to illustrate that which cannot be drawn — N-dimensional space. Filling a multi-dimensional space could be tackled by a number of quite different strategies. We have mentioned chaotic meanderings but, in a man-made approach, we could consider linear control, with planned developments of people and activities working in co-ordination moving in a series of parallel straight lines, meeting an obstruction, re-planning and setting off in a new direction...

Which strategy will find and fill all the niches in the available space: most fully; fastest?

Now, we were not really considering natural environments in the last paragraph; instead we were considering business ecologies, economies and perhaps even crime. In many respects each of these expands within the available space to occupy the available niches which allow them to flourish. Questions of the fastest strategy for occupying the most niches is far from academic — it is vitally important to social and economic development and underpins differing political ideologies.



Fractal 10: N-dimensions?

Nature’s pattern of generating activity and variety to match and absorb available energy is proposed, then, as general and extendible to all systems, including those of politics, economics and business. Political environment dimensions include: social climate, power structures, concentrations of wealth, cultural differences, the rates of change of these, and many more. Economic environment dimensions include: concentrations of wealth, wealth generators, wealth flow, rates of change of these, and many more. Business environment dimensions include: money supply, market demand, skills availability, competitive threat, rates of change of these, and many more.

As with ecologies, it is the very complexity of these multi-dimensional environments that creates niches, which will be filled either by design, or by chaotic speciation. As with ecologies, it is the niches which seem to determine which species survive and flourish and for how long — substantially different from the political ideology of free market competition. To determine which of these approaches might be the more successful, consider open system stability.

Stability

Animals and plants can stabilize in mass without feedback. Organizations can stabilize without feedback. Not that feedback need be absent. For example, flora and fauna exhibit satiation, which tends to prevent further immediate inflow: humans do feel full-up (feedback) as they eat, stopping further eating and stimulating subsequent excretion some twenty minutes after the onset of satiation. But such feedback is not essential to stabilization; people who continually nibble at food may never be satiated, but do not grow forever; they stabilize at a mass which reflects a total intake/outflow balance.

Open systems stabilize at high energy levels, not low. The human stabilizes at high mass/potential energy. Interacting systems may be in a state of constant flux; they appear to be unstable in the short-term, but stable in the longer-term. Stability is particularly difficult to define universally, but a new definition of stability is essential to address open systems. The following definition is offered:

A set of interacting systems, itself constituting an open system, may be said to be stable when, over a period of interest, its net configuration entropy tends to a constant value. As real-world systems are open, this definition must apply to any real world system, or system of systems.

In open systems, there seem to be several routes to stability:

- **Complementary sets** — groups of systems with complementary interflows providing some or all of their mutual needs, reducing both local entropy and the need to re-arrange — this reduced need to change is a move towards stability.

- **Preferred Patterns** — positive feedback resulting in multiple points of stability. Interacting systems with positive feedback tend to lock into one stable point, which can prove very resistant to subsequent change i.e. stable.
- **Dominance** in natural and social systems. Ancient Egypt was a social system dominated by a transcendental culture; it proved very stable over a long period.
- **Linear stability** — systems interact linearly within an open set. This may lead to relative ease of design and management, but is highly likely to result in counter-intuitive responses as the linear systems interact with other, generally non-linear systems, e.g. Planned economy interacting with the real, chaotic world of commerce and agriculture.
- **Catastrophic stability** — systems interact non-linearly, between extremes. Such systems can be long-term very stable, e.g. two party politics, function/project switching.
- **Chaotic stability** — members of set behave chaotically, i.e. uncoordinated. Can be very stable, but indeterminate, e.g. Free market economy.

Stability in open Systems

Stability in open systems is really quite unlike stability in closed systems. As the simplest example, consider Figure 64, which shows a bath with taps open and the plug out. As the bath fills, the head of water and hence the outlet pressure increase until a point may be reached at which the level of water in the bath stabilizes. There is no feedback from outflow to inflow. Like other open systems, stability occurs at high energy, rather than low, represented in this case by the potential energy of the water in the bath.

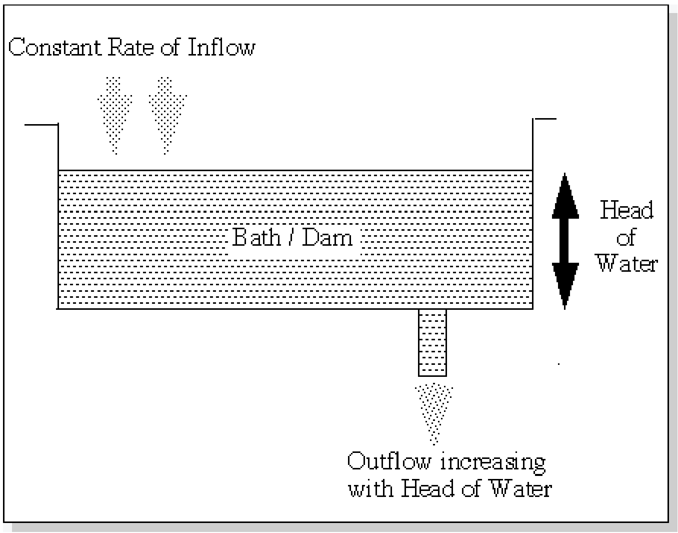


Figure 64: A bath with a constant rate of water flowing in will, provided it is deep enough, eventually reach a stable level because the rate of outflow increases as the bath fills. Eventually, outflow rate must equal inflow rate — stability.

Open systems can oscillate without feedback

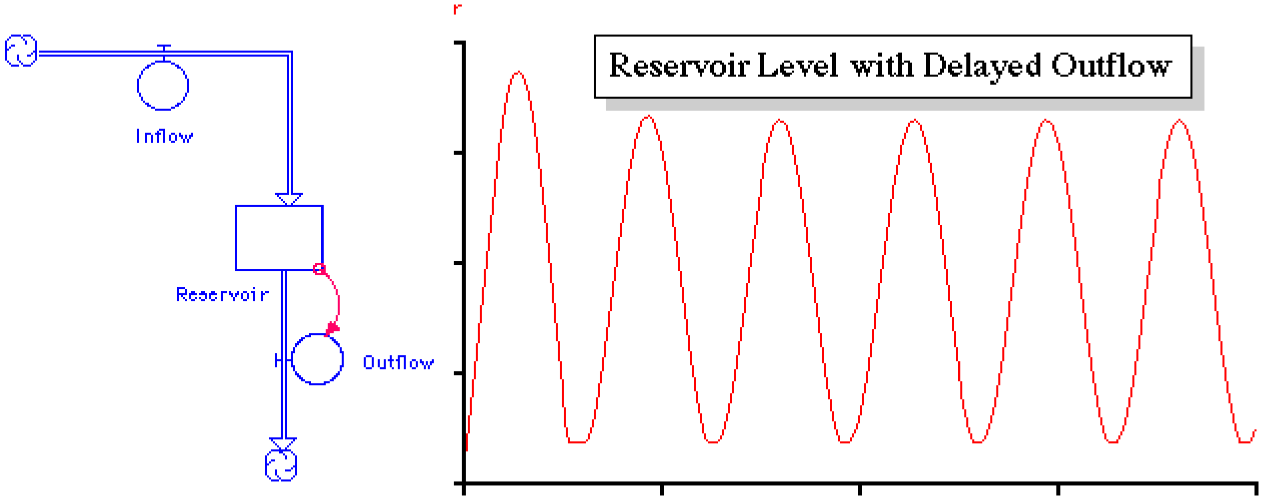


Figure 65: Oscillation in an open system without feedback, and with only one energy store.

The bath analogy is continued in figure 65, where the model represents a constant inflow to (initially) empty reservoir or bath. As before, the outflow is proportional to reservoir contents, but there is a fixed time delay between the level in the reservoir changing and the consequent outflow rate. This delay might equate to a long drain pipe. The result, as the graph shows, is oscillation, without feedback, and with only one energy storage component — the reservoir itself. We are not unfamiliar with this phenomenon: sink outflows gurgle; candle flames gutter.

In these examples, the reservoir and the flame, the resultant state is dynamically stable in the sense that the mean value tends to a constant value over time. Other well-known systems of this general nature include:

- Deciduous trees — leaf-fall is proportional to the number of leaves in growth, but is delayed by the seasonal changes.
- Delivery systems — deliveries are proportional to the number of products in manufacture, but delayed by the need to accumulate a viable load.
- Government budgets — constraints or de-restrictions are proportional to the number of problems caused, but delayed by the annual budgeting cycle and by the time taken to perceive the problems.

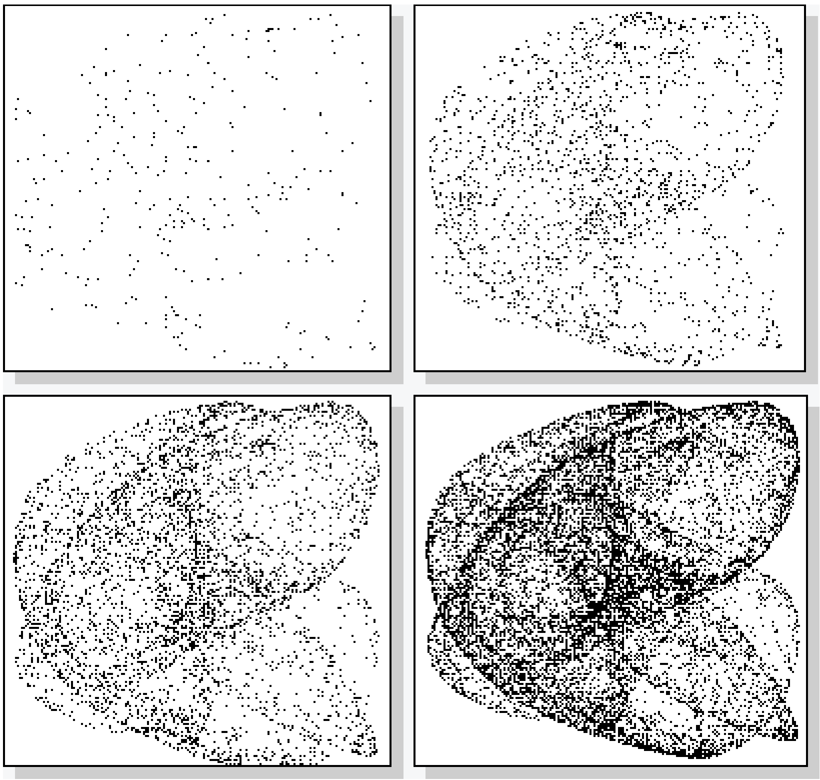
In each case, the open system may oscillate simply due to the situational structure.

Bounded stable chaos and Poincaré Maps

This book is not about chaos as a subject, there are many books available (see Lauwerier, 1991 for an interesting introduction to fractals and chaos). This book is illustrated with fractals, signifying the generation of (sometimes beautiful) complex systems from very simple sources. Some of the features of chaotic systems have already been introduced in chapter 2, and fractal 11 illustrates some further chaotic principles.

Fractal 11 shows a progressive development of a Poincaré Map reading from top left. The map is created by simple interlinked, non-linear equations which create orbits in a 3-D space. As an orbit passes through the plane of the map, a single dot is recorded. The orbit continues on its path, returning through the plane of the map repeatedly, building the pattern of dots. Watching the build-up, it is difficult to predict where the next dot is going to appear, but — as the figure illustrates — it soon becomes evident where no dots will appear, and where dots are more likely to appear.

The endless fascination of chaotic phenomena is in the complexity of pattern that can be generated by very simple equations. The beauty and elegance of the Poincaré Map is in its ability to show at a glance the essence of that complexity, its clearly-defined boundaries, and the paradox between its short term unpredictability and its long-term predictability. The Poincaré Map also reduces perceived complexity by reducing the number of dimensions in its presentation.



Fractal 11: Progressive Development of a Poincaré Map — de Jong Chaos.

To bring the Poincaré Map and chaos down to earth consider football. Imagine a football pitch, with an electronic detector system which detects the football as it passes through a vertical plane, parallel to the goal posts. The plane may be set anywhere between the goals, but consider it set, say, 15 metres from one of the goals. Two teams start to play, and the detector starts to build a Poincaré map, recording each time that the ball goes through the plane. What would the developing pattern look like?

In general terms, it might look like Fractal 11, or at least the top halves of each of the panels, since the ball cannot go below ground level. I suspect that it would display a sort of "footprint" of the interaction between the two teams. Suppose that the two teams played a second, and a third time. Would the same pattern emerge? Suppose, instead, that we followed the fortune of one team, as it played a number of different opponents. Would the pattern of play of our team imprint itself as a signature, modified but not obliterated by each opponent? I suspect so, because the Poincaré map would record the essence of the team’s style of play, whether they were an attacking team, whether forwards went down the wings or through the centre, whether they used their heads or their feet, and so on.

Suppose, now, that we decided to write a simulation program, to emulate and predict a game of football, from the moment of kick-off to the end. What prospects would there be of the simulation matching reality? For instance, would the program predict where the ball and all the players would be in the 15th second of the 73rd minute? Of course not, such a program could never work. At each kick, on each bounce, with each turn, for every sprint, slide and tackle, there is an uncertainty, an imprecision that defies any notion of simple prediction of effect from cause. Football is short-term unstable, long-term stable, short-term unpredictable, long-term predictable — at least in terms of trends.

Will a first division team beat a fourth division team? We may not be able to predict the kick-by-kick play, but the outcome is less uncertain.What is true for football is true for much of life. Instead of football teams, substitute competing businesses, competing political parties, competing economies, rival families, opposing armies… the list is endless.

While each of these may appear to be highly complex, and while their blow-by-blow activities may seem unpredictable, there is a pattern, a gestalt, an essence which determines the trend. It is this essence which the social genotype typifies, and to which belief systems and shared visions give energy and direction. These underlying patterns may be quite simple, but, as the Poincaré Map shows, we have to develop the knack of standing back in order to see them.

It is more in our natures, it seems, to concentrate on the minutiae, to disassemble rather than to synthesize. In so doing, we may create well-ordered systems only to be disconcerted by their lack of success. Consider football once more; a well-ordered system for playing football is zone defence, with every player allocated a zone; it is often the way beginners are taught to play. Top professional teams tend to be much more fluid in their play, with individuals roaming freely over the pitch, aware of the whole game, probing for openings, backing up team mates, and generally exhibiting superior ball skills. This type of play will almost always overcome zone defence, which is cumbersome, and where loss of a player leaves a hole. Zone defence interferes with synergy and flow between the players. For business or warfare, the parallels apply; structure and order have their place, but they can inhibit synergy, flexibility and flow, and may cause fatal predictability.

If we think about players as open, interacting systems, and if their behaviour is chaotic yet consistent, then the question of this longer term stability arises. How can open systems, often without feedback, be stable in a chaotic environment?

Chaotic systems at work

As fractal 10 showed, chaotic systems may be well bounded and often predictable in terms of what they will not do. Many chaotic systems are long-term stable, short-term unstable, including: the weather, the stock market, war & conflict, competitive sport.

Consider the football team again, if only because it is such a well-recognized analogy. There may be chaotic activity, but the whole team is working to a strategy, aiming for a goal. Seen by itself, the path of an individual player presents a meandering path, given meaning only when whole game is seen. Consider engineers in a manufacturing organization looking for new tasks, proactively seeking problems to solve; there is a direct analogy to the football team.

Consider marketing for a new business; is the marketing forecast intended to predict an unpredictable future? Some companies think so, and measure marketing success by accuracy of prediction, not be the level of business achieved.

Chaotic stability

Chaotic systems present difficulties in predicting the next event, but are not random. Chaos arises in non-linear systems where there may be many concurrent, but uncorrelated events, and where there are chains of events such that each outcome is related to some previous events or causes.

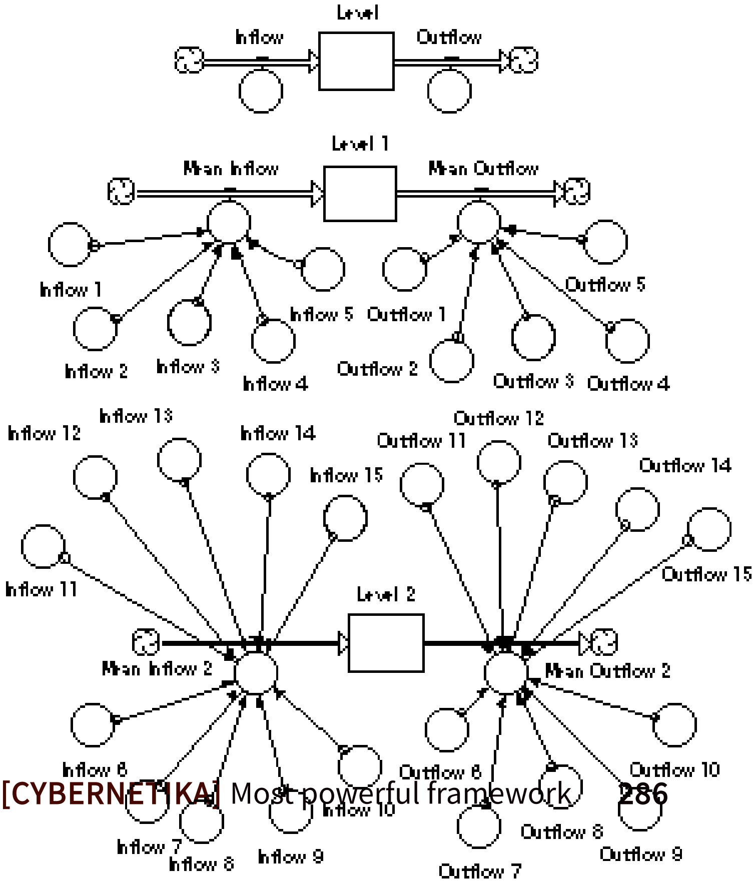
A free-market economy operates on the basis of a wide variety of companies, each unco-ordinated with respect to the others, sharing the same profit goal; it is this common goal that offers chaotic stability. Nature, similarly, evokes a multitude of concurrent, uncorrelated activities to maintain the coherence of populations and to gradually evolve predator / prey performance. Chaos, paradoxically perhaps, seems to contain the seeds of stability. It is ironic, then, that individuals within organizations seek to eliminate the chaos, to so regulate and control activities into linear, "well-behaved" processes that any variability is driven out. It seems more than likely, even inevitable, that their efforts — if successful — must inevitably lead to their eventual downfall! Happily, our organizations may be so transient that they, too, rise and fall chaotically to create a dynamic stability — observing the effects of chaos requires that we stipulate a time frame!

Chaotic stability simulation

Sampling theory shows that the proportional variability between samples goes down as the size of the sample increases. Pollsters trying to predict the outcome of an election are aware — painfully aware, judging by their lack of success in recent years — that small samples can give erroneous results. This idea of sampling is reflected in the following models.

Figure 66 presents three very simple models of a system, marked level 1, level 2 and level 3 respectively. Each model has the same mean inflow and outflow, except that level 1 has one source and sink, level 2 has five sources and sinks and level 3 has ten sources and sinks:

- Each inflow and outflow is independently random.
- Mean inflow is the same in each model.
- Mean outflow is the same in each model.



Provided that the inflows are mutually independent, and the outflows are also mutually independent, it might be expected that peaks and troughs in flow would tend to iron out rather more when there are more sources and sinks than when there are less.

Figure 66: Three representations of unco-ordinated inflow/outflow systems.

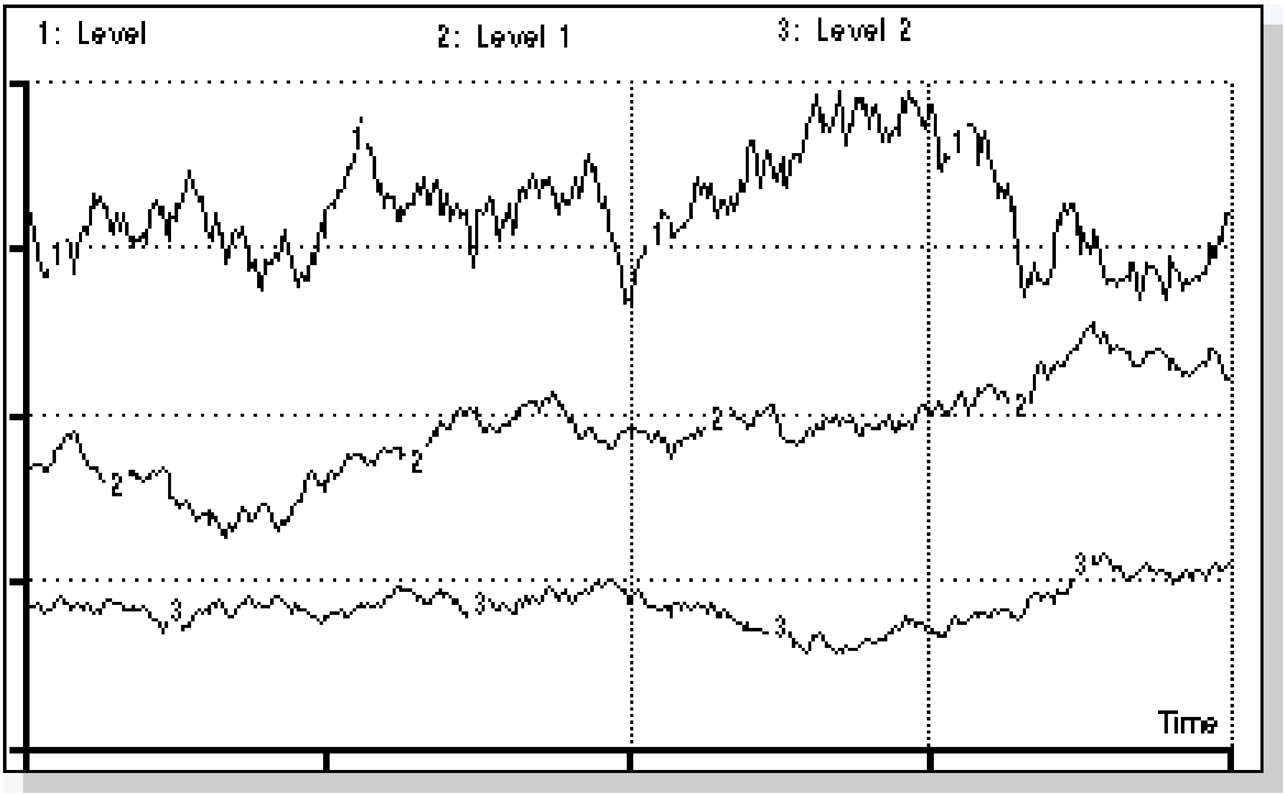


Figure 67: Simulation results from the models of figure 66.

Figure 67 confirms that expectation. Level 1, at the top, is much more variable than level 2, with five inflows and five outflows; level 2 is, in turn, more variable than level 3 with ten inflows and ten outflows.

As expected, variability decreases with the number of random sources and sinks — provided they are mutually independent. Clearly this is relevant to a free market. A supermarket may keep its shelves stocked by buying the same basic product from a number of different suppliers and, provided they are independent, the supermarket stands little chance of running out. Similarly, we can pop into any supermarket on the off chance, and can be reasonably sure of picking up what we want, if not the precise brand.

So what? So this pattern of chaotic supply and use may give a clue to evolution.

Chaos — Essential for life and evolution?

Variability decreases with the number of random sources and sinks; more sources and sinks enable systems to reduce stock levels without fear of shortage — chaotic systems can therefore be more efficient and are more likely to survive lean times. In Darwinian terms, there is survival advantage in chaotic efficiency. Life self-sustains through a web of interactions between a variety of species — variety being crucial. So:

- Chaotic interflows are more efficient and survivable.
- Chaotic systems sustain variety, by avoiding domination.
- Variety is essential to life.

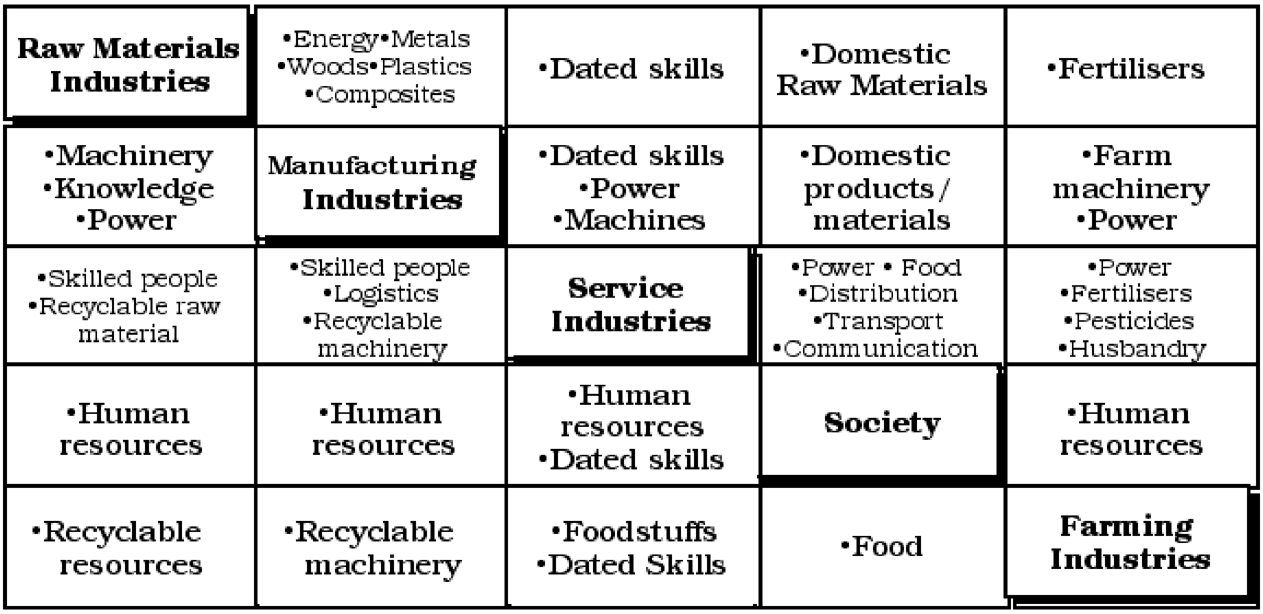
The inevitable question arises: was/is chaos essential for life to evolve? It seems highly likely. If we accept that chaos may have been essential for Darwinian evolution, then is chaos essential for social evolution, too?

That is certainly not the general view, but it is an interesting proposition.

Variety, synthesis and decomposition

Figure 68 shows a highly-simplified representation of a socio-economic systems set. The set is complementary. The representation of figure 68 enables us to see chains of interactions. For example, farming industries provide food to society, which offers human resources and dated skills to various service industries. In turn, these service industries provide power, distribute goods, transport freight and people, and provide communications to society, which also provides human resources to work in the farming industries. That description moved through a closed double helix, a closed chain of interactions in figure 68.

In the figure there are: one 5-loop, five 4-loops, ten 3-loops and ten 2-loops. Moreover, each "system" (e.g. service industries) comprises many concurrent, possibly unco-ordinated and competing elements. The potential for social genotype development is enormous. Stability within such a complex structure — and the figure is highly simplified — could be controlled/planned or chaotic. We have already met the simulation of such a system — see figures 17 and 18. Simulation shows that the long term effects of substituting, say, imported raw material or food supply in place of a home grown commodity impacts all other systems, each gradually moving to a new (uncertain) state affording overall stability, but with every part of the system operating at a different level. It takes a long time for the effects to permeate through the environment, but permeate they do — according to the model.



Raw Materials Industries	•Energy•Metals •Woods•Plastics •Composites	•Dated skills	•Domestic Raw Materials	•Fertilisers
•Machinery •Knowledge •Power	**Manufacturing Industries**	•Dated skills •Power •Machines	•Domestic products / materials	•Farm machinery •Power
•Skilled people •Recyclable raw material	•Skilled people •Logistics •Recyclable machinery	**Service Industries**	•Power • Food •Distribution •Transport •Communication	•Power •Fertilisers •Pesticides •Husbandry
•Human resources	•Human resources	•Human resources •Dated skills	**Society**	•Human resources
•Recyclable resources	•Recyclable machinery	•Foodstuffs •Dated Skills	•Food	**Farming Industries**

Figure 68: Notional chart showing complementary social and industrial systems interchanging variety, synthesizing and decomposing (as in food chain) to create a dynamically stable economy/society, resistant to change and damage, but requiring continual energy-pumping to enable processes. Outputs from the leading-diagonal systems are in their respective rows, inputs in their respective columns, and variety goes into the page. (Compare with figure 17.)

Free market competition

In a free market, a new point of stability appears, paradoxically, to be both guaranteed and yet unknowable. However, there are conditions for a free market to exist, chief amongst which are that, like an ecology, it should have a richness both of variety and of interaction.

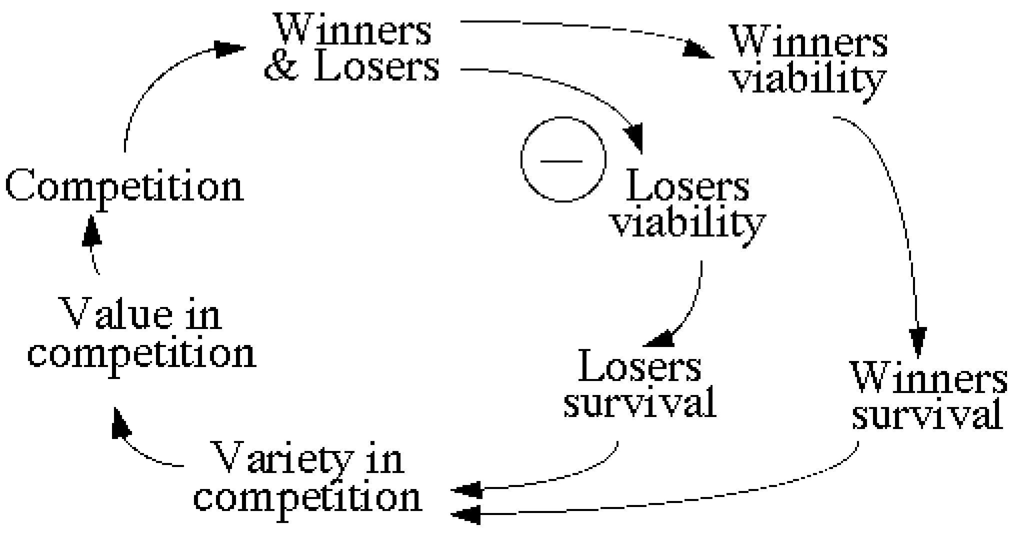


Figure 69: Competition in a restricted environment. The inner loop is negative feedback, progressively reducing competition until, eventually, there is a monopoly.

Fractal 12: Ikeda

Genuine competition invokes losers as well as winners. In nature's ecology, losers often die, but that would be far too expensive a fate for economies. Instead losers must be able to lose yet survive — at least several times.

Suppose, however, there is a small market, with many competitors. There will, inevitably be more losers than winners. See Figure 69. Over time, the variety of organizations able to compete inevitably reduces, losers switch/go out of business. The result is inevitable — monopoly through survival. The only question is: how long does it take? Such questions never get asked, let alone answered, when political ideologies and beliefs rule.

The dynamics of order and disorder

> “It is the nature of an hypothesis, when once a man has conceived it, that it assimilates everything to itself as proper nourishment; and from that first moment of your begetting it, it generally grows the stronger by everything to see, hear, read or understand. This is of great use.”
> — Laurence Sterne 1713-1768

Towards a theory of complexity

We have seen that complexity is made up of: variety, connectedness of that variety, and disorderliness of both. We have also seen that symmetry can engender minimum energy of exchange in complex systems, offering survival advantage. It seems, too, that open, interacting systems naturally evolve dynamic stability of synthesis, decomposition — at the "edge of chaos".

Social, organizational and transcendental systems evolve genotypes analogous to nature’s. The social genotype hypothesis proposes how and why organizational/social systems resist change, adapt and evolve only slowly. The social genotype may even be seen more as an extension of the biological genotype than merely an analogy.

Behind these phenomena and perceptions we see, not control and regulation, but complementation and connected variety as the bases for open, interacting systems stability. It is also evident that open, interacting systems stability breaks down when connected variety reduces in a changing environment, owing to inability to adapt to changing environment.

Lastly, it seems that chaotic systems are potentially more robust than those we seek to control; this paradox is at its most apparent when comparing planned and free-market economies. No matter how careful the planning of the former, stability breaks down with time. On the other hand, the free market economy, while seemingly not breaking down, is unpredictable and may adopt temporary states that are less than desirable. Ecologies respond not dissimilarly.

These observations and perceptions are so consistent and widespread, apparently covering systems of all types and sizes, that the possibility of some straightforward underlying theory must be considered. In seeking any theory, it is useful to find invariances. One such invariant is that systems come into being, exist for a time, then decay or collapse, to be replaced by other systems. Evidently, there are opposing influences, some promoting stability, others promoting decay, the whole promoting "life-cycling" — the continual formation and breakdown of open, interacting systems.

Open systems interactions

We can make some general observations, based on previous chapters:

- Energy creates disorder. If we heat a substance, its molecules vibrate, there may be a change of state. If energy is injected into an argument, disorder may result. If solar energy is radiated into an ecology, speciation occurs, activity levels increase, movement increases.
- Variety interacts to form systems. Sometimes the interaction is uneventful, sometimes inimical, but sometimes the parts find mutual benefit. On those occasions, separation would be unnecessary or disadvantageous, and the varieties may form a system.
- Systems reduce entropy. Because of the complementary nature of the parts from which a system must be formed, both the parts and hence their intra-connections form a pattern. That pattern represents reduced (configuration) entropy, a localized ordering against a disordered backdrop.
- Systems break apart sooner or later, increasing entropy back towards the state before the system formed.
- Previous bullet-points above present a concept of continual change over time in which:
    - The mean level of disorder is increased by energy.
    - The rate of change from order to disorder to order is increased by energy.

Energy, it seems, not only creates disorder. For open interacting systems it also creates order from that disorder.

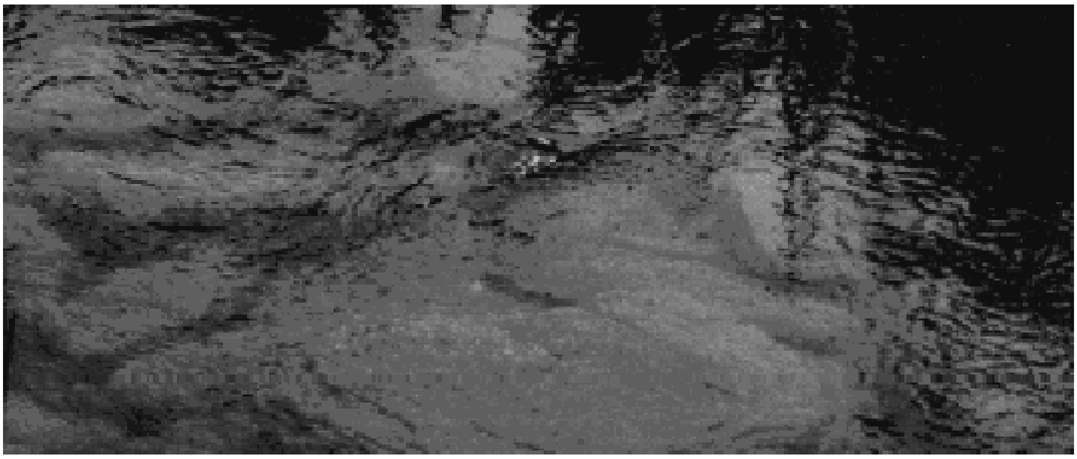


Figure 70: Open Interacting system analogy. Surface of a pool with submerged pump causing water to well up. The surface shows ephemeral whirlpools and eddies, each stable for a time, but each deforming, the water molecules becoming absorbed into other "systems". Each system is either forming from disorder, maintaining order, or becoming less ordered — hence each "observes" internal order, external disorder — "edge of chaos". The whole behaviour is pumped by the unseen energy source.

A useful analogy to understand this view of open interacting system life-cycling is given in figure 70. It shows the surface of a pool which contains a submerged water-pump, causing the water to well up to the surface. The resulting surface is turbulent, with swirls and vortices forming and reforming, some lasting, some ephemeral, some large, some small, the whole presenting self-similar patterns, driven by the energy from the pump. Were the pump to stop, the patterns on the surface of the water would die away. Were the pump to increase its flow, the surface would become more turbulent, more systems would form and reform, and at a higher rate. At a still higher level of energy, different types of pattern would occur, with bubbles, spouts and fountains.

So it seems to be with all open interacting systems. An ecology employs energy from the sun, which causes growth, activity, formation of floral and faunal systems, decay and reformation. While the solar energy lasts, the life-cycling continues. Where solar energy is greater, the number of species and their rates of growth and decay increases — typically, rates of growth and decay are five times greater in a tropical rain forest than in a tundra.

Romme and Despain (1989) investigated recurrent fires in Yellowstone National Park. There were relatively few occurrence of major fires, although minor fires, initiated by dry weather and natural or man-made sources, occurred frequently. Between the early 1700s to the summer of

1988, there were major fires in 1690-1709, 1730-1749, 1850-1869 and 1988. Why the unexpected pattern?

After each fire, the ground was scorched. A few plants were adapted to survive fires, and their deep-lying structures grew to form a new, verdant growth of initially-soft plants. Birds, bats, animals and the wind brought seeds into the area. After a time, softwood trees started to grow, shading the undergrowth and taking some of the sun's energy for themselves. As a result, the pattern of forest floor plants changed, with different species emerging that were more adapted to these conditions. As softwood trees eventually died, they rotted down in the undergrowth under the action of decomposing bacteria, providing a mulch for new growth.

Hardwood trees emerged, with their slower growth. Hardwoods grew taller, creating a canopy with which to catch most of the sun's energy, shading the forest floor and drawing up moisture and nutrients. The forest floor plants died away, deprived of light, moisture and nutrient. Eventually, the dominating hardwoods died too, but when they crashed down, they did not create a moist mulch; instead they created a dry tinder which could support a major fire. One lightning strike in the right place would set the whole cycle in motion again.

The Yellowstone park cycle presents a striking example of life-cycling. It is all there: speciation, variety, stability, emergence of dominance, suppression of variety by dominance, tendency to moribund, monotonal system, collapse, speciation... Note how dominance suppressed variety by starving lesser species of sustenance, but in so doing brought about its own downfall.

Civilizations behave similarly. The Ancient Egyptian civilization grew rapidly using energy from the sun and fertility from the Nile. With such exceptional and dependable energy, the civilization produced a profusion of open interacting systems including the cultural and transcendental systems introduced earlier. Dynasties came and went. Egypt conquered many lands and took tribute to maintain the flow of energy into their civilization. Eventually, however, the civilization decayed as other lands grew stronger, and as its internal political and economic systems became moribund.

Businesses behave similarly, rising and waning with greater frequency. IBM, like Ancient Egypt, grew particularly large, and dominated in part by virtue of being first on the scene. IBM was slow to adapt to the advent of smaller, networked desktop computing systems, clinging instead to the larger mainframe machines which had made it great. Recent tribulations within IBM mirror those in Ancient Egypt and in Yellowstone Park.

Nature and the second law

One of the central tenets of classical physics is the Second Law of Thermodynamics. It can be stated in a variety of ways, including:

> “The processes most likely to occur in an isolated system are those in which entropy either increases or remains constant”

The Second Law has been used to predict the gradual disordering and eventual cooling of Universe, and it is evident for many physical phenomena.

A key phrase in the Law is "...in an isolated system...". But the natural and social worlds are not isolated. So, does the Second Law apply, and if so, how? This appears to be a substantial issue. While mixing milk and tea increases entropy, what about the synthesis of tea and milk production? These include: the synthesis of grass and tea-bushes; milk formation in cows; bottling, packing and distribution. All of these incur increasing order before the milk mixes with the tea. Looked at overall, has entropy increased or decreased?

Further, life has gradually evolved on Earth, and is still evolving today. It is difficult not to see this slow, inexorable evolution as increasing order. It is reasonable to conclude as follows:

- Nature does not challenge the second law of thermodynamics, because nature's evolution does not satisfy the condition of "an isolated system".
- The second law holds little relevance for open, interacting systems which include all those around us. (If a system were truly isolated, how would we even know of its existence?)

We need a law to complement the second law of thermodynamics that does apply to open interacting systems — the law of complexity. In seeking for such a law, or laws, consider first the unified systems hypothesis.

The unified systems hypothesis (HUSH)

As part of my research, I have developed a so-called unified systems hypothesis USH) over several years. My students have taken to calling it Hitchins Unified Systems Hypothesis (HUSH) and, since that title results in a nicer acronym, please forgive me if I follow their lead. HUSH is more fully explained in putting systems to work, (Hitchins, 1992), and in the journal Systems Practice (December 1993). A brief résumé of the principles follows.

There are seven principles which together comprise the unified system hypothesis. Individually, they may seem simple, even axiomatic. Together they may seem rather less self-evident. First the principles.

The principle of system reactions

The principle of system reactions is stated as follows:

If a set of interacting systems is at equilibrium and, either a new system is introduced to the set, or one of the systems or interconnections undergoes change then, in so far as they are able, the other systems will rearrange themselves so as to oppose the change.

An equivalent statement proposes that, after the perturbation, the set of systems moves towards some new equilibrium. The principle, based on Le Chatelier's Principle, says nothing about the manner of that movement; it may be linear, non-linear, periodic, catastrophic or chaotic, but each response will eventually reach equilibrium. The contention of HUSH is that the principle applies equally to interactions between economic, political, ecological, biological, stellar, particle or any other aggregations which satisfy the definition, system.

The principle of system cohesion

The principle of system cohesion is stated as follows:

> “Within a stable, interacting, system set, the net cohesive and dispersive influences are in balance.”

For physical systems such as a star with its planets or the quarks in a neutron, such a statement might seem axiomatic, or perhaps another way of looking at Newton's third law. The proposition, however, is that the principle applies to all interacting systems, social, economic, political, etc.

The principle of system adaptation

The principle of system adaptation is stated as follows:

> “For continued system cohesion, the mean rate of system adaptation must equal or exceed the mean rate of change of environment.”

The principle is evident within biological systems, and is under-pinned by Darwin's theories. It seems likely that the sudden extinction of the dinosaurs, and of some early S. American cultures, are spectacular examples. The proposition is that it applies to all interacting, systems including man-made systems.

The principle of connected variety

The principle of connected variety is concerned with stability of interacting systems:

> “Interacting systems stability increases with variety, and with the degree of connectivity of that variety within the environment”

At first appearance, this principle may seem obvious. Certainly, if we look at natural habitats, we see stability dependent upon a web of interactions between plants and animals, with food chains, survival, reproduction and natural selection creating a complex continuum. If we look at the human social world, we see similarly-complex webs of social interchange, to the extent that governments sometimes intervene in business to unravel the web.

In the UK, as already noted, there is a move to introduce "trust status" for hospitals and schools, by which is meant granting them relative independence so that they are freed from the web of bureaucracy surrounding state schools and hospitals. Once freed, the argument goes, these schools and hospitals will be free to change and hence to become more competitive. It is also true, of course that, once freed, schools and hospitals are free to make mistakes — the web of connected variety can be looked upon as a safety-net, too.

The principle also invokes notions, expressed earlier, of minimum, useful, limited and excess variety. Not all variety need be connected within a set. Unless a minimum degree of connection is made, the set will not be viable. Beyond that, additional connections may be useful, for instance in enabling the system to tolerate some level of damage. Excess variety might include that which makes a set of interacting systems so stable as to resist desired change.

The principle of limited variety

The principle of limited variety is stated as follows:

> “Variety in interacting systems is limited by the available space and the degree of differentiation (degrees of freedom).”

The principle is axiomatic once "space" and "degree of differentiation" have been established. This principle is important because it provides an essential counterbalance to other principles. The principle of connected variety, for example, might suggest the notion that stability could be increased without limit simply by increasing (and connecting) variety. The principle of limited variety shows that infinite stability cannot occur.

Space, as referred to in the principle, has to be considered in context. For example, the space within a rain forest for species is increased by the amount of energy entering the forest, which increases the potential niches. The variety of species observed within that space is determined by our perception that one specimen is significantly different from another.

The principle of preferred patterns

As the weave of interactions between systems becomes more complex, it is increasingly likely that feedback loops will arise, some perhaps acting through many successive systems and exchanges. The prospect increases of non-linear interacting system behaviour. The occurrence of positive feedback loops is to be expected, if only because of resulting delays, and leads to the principle of preferred patterns:

> "The probability that interacting systems will adopt locally-stable configurations increases both with the variety of systems and with their connectivity."

Positive feedback has, in the past, been considered as the basis of instability. It can be shown, however, that positive feedback in a network of largely negative feedback relationships results in the adoption by the systems concerned of one of a number of possible, highly-stable states.

The principle of cyclic progression

The last of the HUSH principles addresses the phenomenon which we all recognize, that systems do not last for ever. (The second law of thermodynamics concurs, of course, but HUSH goes further.)

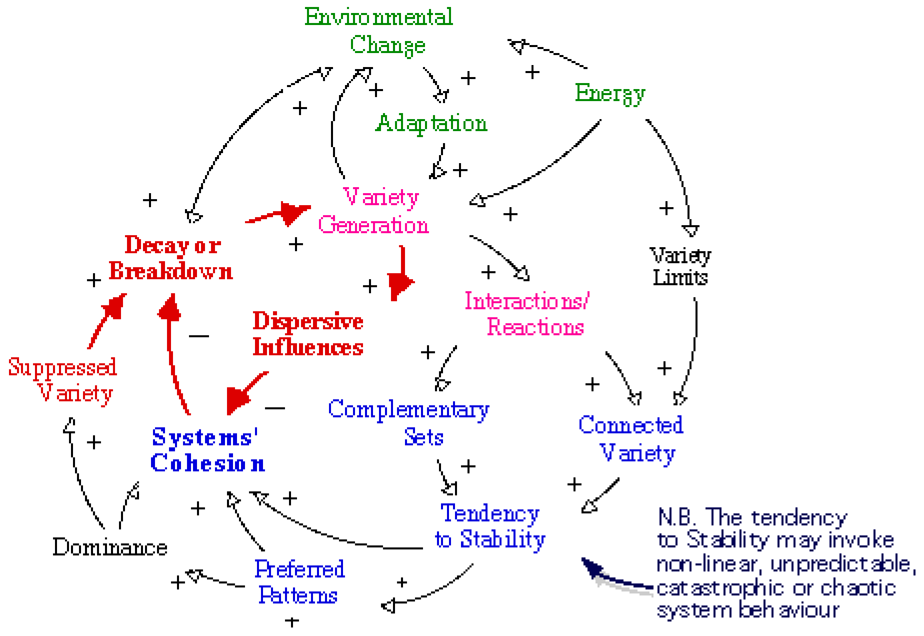
Such observations support the principle of cyclic progression:

> "Interconnected systems driven by an external energy source will tend to a cyclic progression in which system variety is generated, dominance emerges, suppresses the variety, the dominant mode decays or collapses, and survivors emerge to regenerate variety."

The weight of evidence suggests that there may indeed be a repeating pattern in systems where variety, the mediator of stability, is suppressed by dominance, which in turn leads to vulnerability through inability to change.

HUSH Map

The seven HUSH principles may be brought together into a single explanation of the life cycle of sets of open interacting systems. Figure 71 illustrates the HUSH principles taken together as a set. To follow the map, start at energy, upper right, and follow the map around, generally moving clockwise. Energy drives the cycle; the more energy, the more variety and the more mobility within the variety. With more energy comes a greater probability of interaction between the varieties, some of which will result in complementary interaction, some in dispersive influences. Complementary interaction reduces the energy consumed by the complementary systems in question, since they have some of their sources and some of their sinks in the vicinity. Further interaction sees more complementary systems attaching themselves, or inimical connections disrupting those which had connected.



N.B. The tendency to Stability may invoke non-linear, unpredictable, catastrophic or chaotic system behaviour

Figure 71: The HUSH map, showing how the various HUSH principles combine to illustrate the formation, life cycle and eventual degradation of sets of open, interacting systems.

Further systems may join, if complementary. Their interchanges with the other varieties within the set may be continuous or stochastic. Sets of complementary, open, interacting systems may form, and may create a local "web" of stability surrounded by a sea of temporarily unconnected systems. One or two of the systems may influence the set, perhaps by transforming a key variety, or perhaps by transforming more inflows to outflows than others in the developing set; this is the onset of dominance. Dominance is not, of itself, deleterious to the set, indeed dominance can make the set behave in a stable manner, the dominant member influencing behaviour of the whole and, as it were, pointing all their transformations toward a particular direction. But dominance can suppress variety, just as a dominant tree can shut out the light, and drain all the sustenance from ground level plants, preventing their growth. Once that happens, the behaviour of the set tends towards that of the dominant system, the sets becomes "monotonal" and may not be able to adapt to change. This is the onset of degradation and collapse, after which the cycle starts again.

Working around Figure 71, it is possible to see each of the seven HUSH Principles. Together, they offer explanations consistent of complex system life cycle behaviour. From Figure 71:

- More energy creates faster environmental change, more adaptation, more reaction and interaction.
- More energy creates more speciation, raising the limits to variety.

- More reaction and interaction, together with more variety, increases the probability of complementary systems existing and coming together.
- Complementary systems provide a basis for stability through connected variety.
- Stability is maintained by continual resupply of connected variety (as the human body remains stable only if fed with appropriate food and drink) which in turn depends on continued energy supply.
- System cohesion develops as a balance between the connected variety, promoting stability, and unconnected varieties which continually influence dispersion of the cohesive set.
- System cohesion maintains its form through either chaotic/catastrophic/linear/stochastic interaction, or through the development of preferred patterns leading also to dominance.
- Dominant systems tend to absorb/monopolize energy, suppressing variety within the set either inadvertently or by design.
- Cohesive Systems, but with suppressed variety, remain stable until an environmental change or a dispersive influence requires them to adapt. If they have become monotonal, able to behave in one way only due to lack of variety, they degrade or may collapse.
- The degrading or collapsing set provides the variety of its parts to start the cycle again.

Once this cycle, and particularly the reasons for its transition from state to state, are understood, interesting insights emerge. The state changes are more easily seen in figure 72. From the figure, it is evident that the way to create and maintain cohesive interacting systems is to maintain the level of connected variety while at the same time combating any dispersive influences. The figure also shows that seemingly stable system sets may in fact be moribund, waiting only for a change in the environment to reveal their susceptibility. Typical of such systems are organizations that, to survive a recession, have divested themselves of useful variety in pursuit of so-called efficiency. The result of their efforts is the ability of the organization to do only one thing. Should that one thing not suit the re-awakening market at the end of recession, major change in the organization is inevitable. The figure does not suggest the existence of a simple, direct return from moribund to cohesive, it being necessary to traverse clockwise through the upper two states. For the super-efficient, impoverished variety organization, this means either total demise or at least major re-organization.

Suppose instead that the objective is to damage a cohesive interacting system, to render it unstable. Figures 71 and 72 suggest that there are, again, two complementary methods. First, eliminating variety will render the system set moribund; this may be sufficient in a dynamically-changing environment, but may be too slow otherwise. Second, there may be a need to introduce a dispersive influence. As we have seen from the social genotype, that dispersive influence could well be brought about by an assault on the culture or belief system as practised by opposing armies in war, using propaganda and false intelligence. A new, vigorous belief system would have a similar effect.

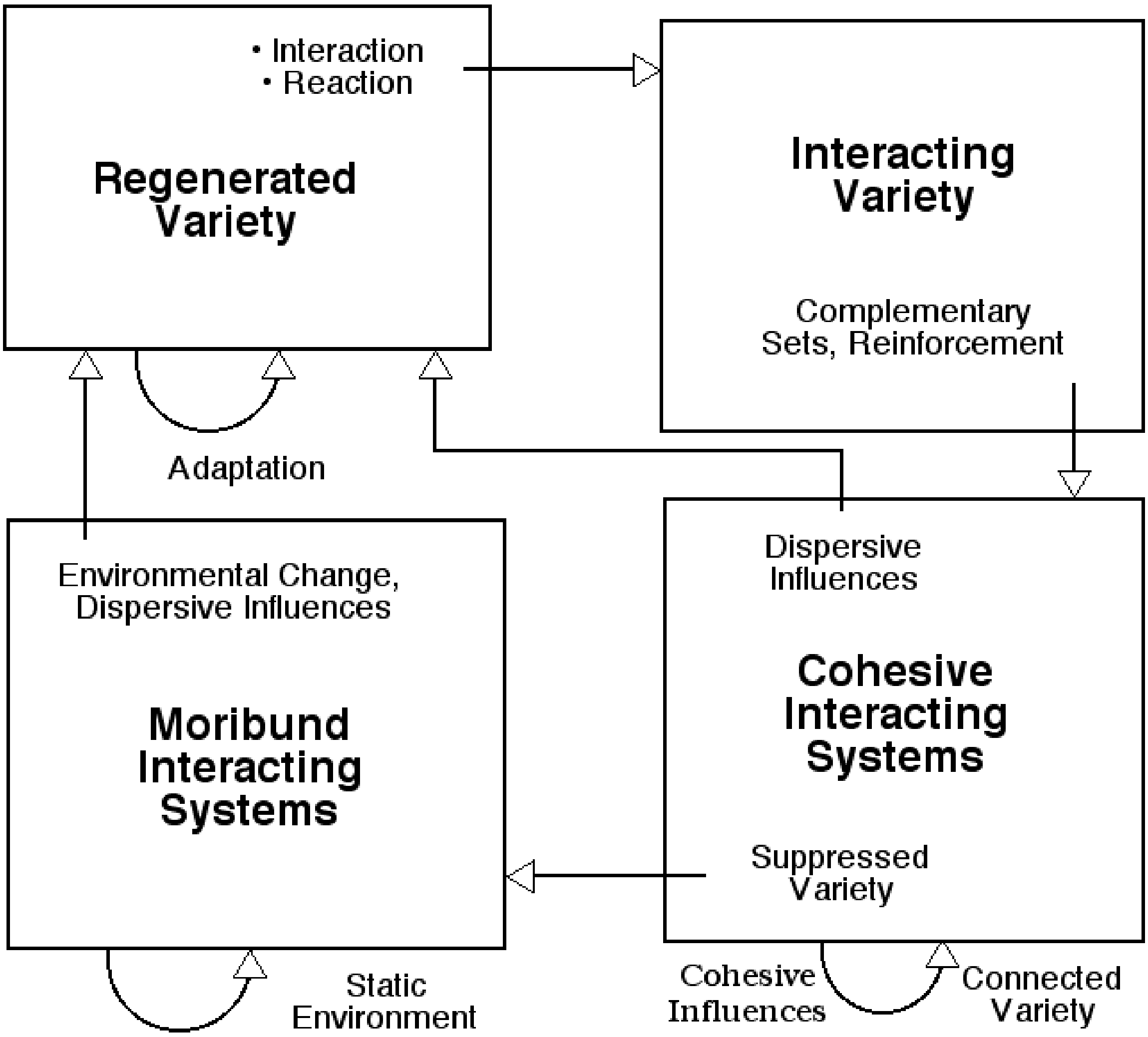


Figure 72: HUSH state-transition diagram, showing four states in the formation and dissolution of Open Interacting Systems, and the causes of switching between those states.

If the intent is to develop or maintain a long-lasting, extremely robust system, then a different tack may be necessary. The route to domination is unsuitable — that is the path to (possibly) effective, but short-lived stability. Instead, the path to follow is shown on figure 71 as going direct from tendency to stability to systems' cohesion. There are several options along this route, but they share one feature no domination. Probably the soundest route is towards chaotic open interacting systems. Besides free market economies, other examples of this path to cohesion are followed by nature's systems and, perhaps unexpectedly, by some women's organizations.

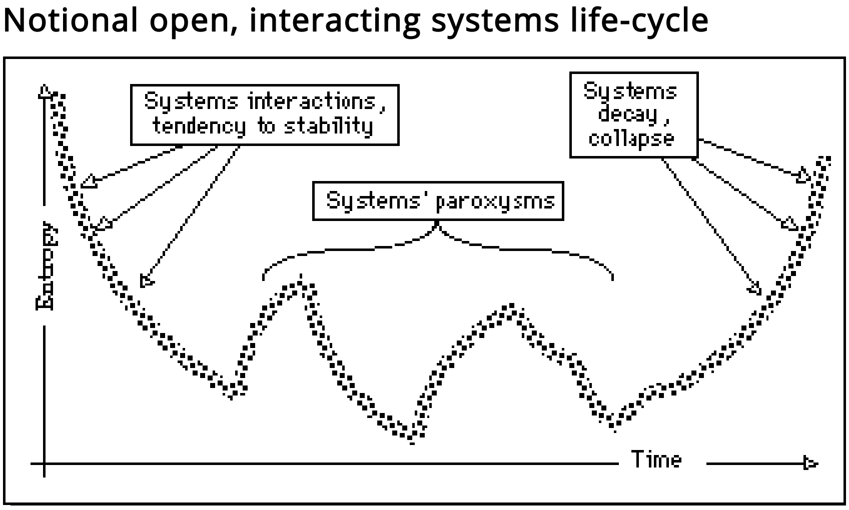
Women do not suffer from the excess of testosterone which pervades male organizations, requiring the male to assert his dominance. Instead, many women seem able to work co-operatively in groups without domination, some serving as co-ordinators to provide necessary and sufficient organization and infrastructure for stability.

We may use HUSH principles to understand and discuss complex and sensitive situations, since the principles and the map offer a basis for objective analysis and synthesis. For example:

- If a (dominant) premier were to eliminate from their cabinet all members who did not share that premier's views, then HUSH proposes that this suppression of variety will be followed by a degradation and break-up of the cabinet.
- If a union of states were dominated by one country, with others held as vassals by terror, economic sanction, secret police, suppression of dissidents, etc..., (stable by virtue of little variety but much connection) then any loosening of the grip by the dominant country would result in a domino break-up of the whole set, with the suppressed energy being released to generate new variety.
- After such a domino collapse, a plethora of political views and parties would generate, but would rapidly interact to produce many fewer, but larger and more powerful, sets as order emerged spontaneously from disorder.
- At the time of writing, the european union is considering whether to open its doors to eastern european nations, formerly of the soviet union. From a HUSH perspective, the choice is straightforward. Stability of the european union will be maintained and enhanced only of the variety represented by these new nations is well-connected to other members of the set, by virtue of cultural, social and economic interchange. If new members are not well-connected, then they are just as likely to act as dispersive influences as not.
- On the subject of the european union again, HUSH suggests that attempts to unify the member states, to reduce their variety, to make them conform to some euro-standard, will tend to reduce the stability of the whole. Connected variety is their potential strength.
- If a body is experiencing breakdown from dispersive influences, then the situation may be stabilized, not by control, but by the introduction of complementary systems which bind to the dispersive influence and to the remaining cohesive systems set. An ethnic minority

which feels isolated and embattled may be brought into a more comfortable state by the introduction of a system for promoting the values of their culture to the other ethnic groups, by encouraging the adoption of a lower profile for those features of the culture causing most dispersion, and by cross-connecting the many varieties to their mutual benefit.

- An information system comprising many distributed computers may be made more robust by employing an open systems interconnections and a variety of different processors and architectures. (While short-term economics might propose uniformity, HUSH promotes connected variety.) When change comes to the information system — new users, new needs, new applications, changing environment — the ability of the information system as a whole to adapt and evolve without interruption will be enhanced because some of the processing and software will already be suited to the change. A connected-variety system is not susceptible to unforeseen "systematic" weaknesses, as would be a system made from uniform processors and software. Hubble space telescope pointing hardware had to be replaced after a relatively short time in space owing to systematic errors in design which, as the components were replicated, affected all of them. Connected variety information systems are used for such essential applications as railway signalling, where positive and negative logic, together with alternate algorithms undertaking the same calculations, are used to ensure no single errors cause failures. Long-term economics favours connected variety, not uniformity.



It would be useful to try some mathematical proof of HUSH, and that is both possible and underway. As a part of that "road to proof", models of system behaviour can be built. In the same way as nature and Nurture were simulated previously, it is possible to build a simulation of figure 71, and to run it to see what happens.

Figure 73: Expected results from simulating HUSH

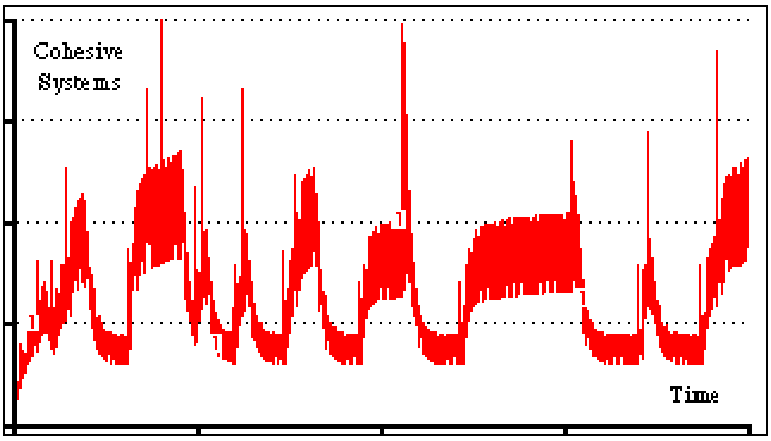
Figure 73 shows what we might expect to happen, if the explanation of the HUSH model is anything to go by. In the figure, the Y-axis represents entropy, the degree of disorder. As varieties cohere, we might expect a drop in overall disorder. As dominance emerges in sets of systems, however, we would expect them to break up and eventually to reform into other variety groupings. Eventually, perhaps, we might expect a major decay as shown at the right of the figure, in the event of a reduction in energy to maintain the generation and mobility of variety. These predictions are all consistent with the theory of complexity.

So what does the dynamic simulation really show?

HUSH Map dynamic simulation

In figure 74, the y-axis is not entropy, but the number of cohesive systems within the overall number of systems at any time. Cohesive systems form a pattern in an otherwise random sea of varieties, so entropy goes down as we go up the Y-axis. The graph should therefore be upside down compared with figure 73 — and that is broadly what happens. The general outline of figure 74 is of the same shape as figure 73 would suggest, but with the added feature that there is a rapid variation in the number of cohesive systems. It is as though stability is being achieved on two levels. At the higher level, there is a relatively slowly changing pattern, but when viewed more closely, there is a highly dynamic pattern. (The simulation assumes a constant energy inflow, so the tail at the right of figure 73 is not expected to appear in figure 74, and it does not.)

Such models are notoriously difficult to validate , and it would be quite wrong to interpret the simulation too freely, but the model does suggest chaotic behaviour in between the high spikes, which presage the break-up of cohesive groups as a result of dominance. Indeed, if the simulation is adjusted to avoid dominance, then a stable — but chaotic — state results.



Stable, but chaotic? The number of cohesive systems still varies rapidly, but between limits which form smooth, horizontal contours. There are no paroxysms, suggesting — perhaps — that chaotic systems may be dynamically stable as expected.

Figure 74: Simulation of HUSH, as presented in figure 71.

A law of entropic cycling

> “If you're anxious for to shine in the high aesthetic line as a man of culture rare, you must lie upon the daisies and discourse in novel phrases of your complicated state of mind, the meaning doesn't matter if its complicated chatter of the transcendental kind and everyone will say, as you walk your mystic way.”

> "If this man expresses himself in terms too deep for me, why, what a singularly deep young man this deep young man must be!"
>
> — W. S. Gilbert, 1836-1911

The law of entropic cycling

HUSH from chapter 12 provides the basis for conceiving and understanding the value and application of a new "Law of complexity". What would such a new law of entropic cycling be about? Like the second law of thermodynamics, it will be about everything in general, but about nothing in particular. In fact, it should complement the second law; if that applies to closed systems, then the law of entropic cycling should apply to open systems in a not-dissimilar way.

The following is proposed as a new law of entropic cycling:

> “Open, interacting systems' entropy cycles continually at rates and levels determined by available energy”

The law applies to many, open, interacting systems, containing many systems in self-similar hierarchies, with the ordering mediated by connected variety. In this it is unusual, since it does not seek to operate within any boundary, unlike the second law which, by referring to isolated systems, implies a boundary across which energy does not pass in either direction. The law of entropic cycling applies to a never-ending network of systems, providing a basis for understanding parts of this infinite network without bounds or preconceptions. Instead of isolation, the law of entropic cycling embraces openness and interchange, with energy entering and leaving any part of the infinite network that may be of interest.

At first reading, the law of entropic cycling may appear a disappointment. After all, how can it be used in connection with, say, a social system, an economic system, or an ecological system? First reading of the second law of thermodynamics may engender similar reactions, but that Law is one of the cornerstones of physics and engineering. The law of entropic cycling has to be seen in context. It applies to open, interacting systems which are in a state of continual, dynamic change. The law is scale independent and type independent: it applies to large and small, systems of any kind. The law proposes that systems, far from decaying with time, recycle themselves for ever, provided they receive energy continually.

How might we apply the law? In essence, we already have done so, at least by example. The last chapter showed examples of HUSH analysis of complex situations; each is an example of the law of entropic cycling in operation. For open, interacting systems, the law of entropic cycling proposes that:

- Complexity can be measured as (configuration) entropy; the greater the variety, connection and tangling, the greater the disorder in pattern.
- Energy may take many forms including wealth, ideology, belief, and many more, according to the types of system of interest.

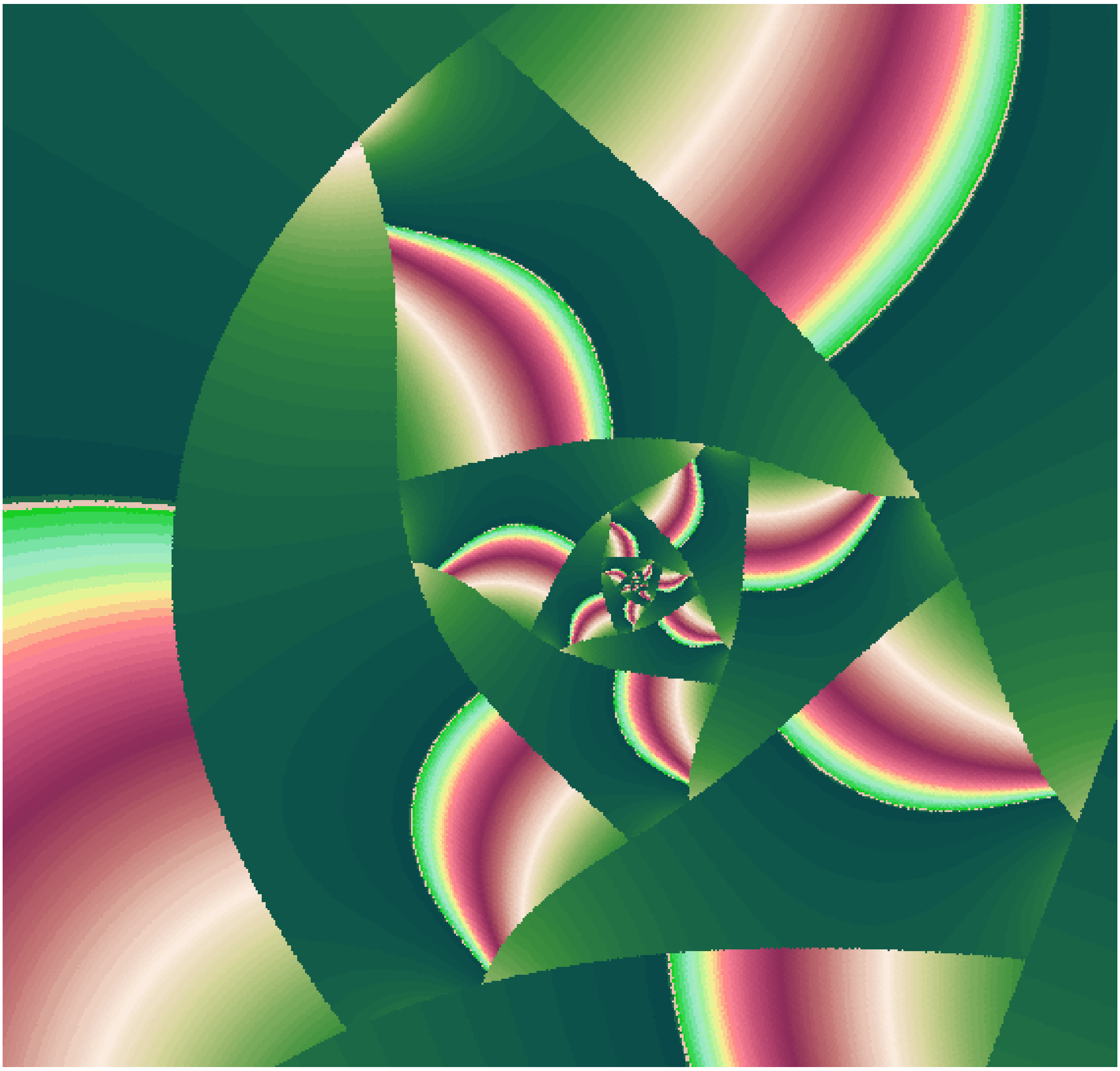
A reduction in energy inflow to zero will result in zero entropy, eventually — consistent with the second law.

- An influx of energy will increase the general level of entropy, i.e. create more disorder — consistent with the second law.
- A steady flux of energy will result in continual entropy cycling, but not necessarily continuous entropy cycling, i.e. the rate of change of entropy need not be smooth.
- A rise in the energy flux to a new level will increase the rate of entropy cycling.
- There is a balance at all times between the energy influx and the total energy contained in, and utilized by, systems as they traverse the HUSH life cycle — conservation of energy applies for social and transcendental systems, too.

Using these precepts, new viewpoints about social systems behaviour are possible concerning, for example, criminality and the law, education, committees, power structures, organizational behaviour, etc. similarly, new viewpoints emerge about economic systems, engineering systems, transcendental systems, and even physical systems, particularly at quantum level for example.

Seeing through the dark glass

We have come a long way since thinking about complexity as variety, connectedness and disorder. The thirteen chapters have painted on a wide canvas, looking at beliefs, psychology, ancient history, economics, politics, social science, genetics, heredity, Darwinian and social evolution, business, organization, behaviour and many, many more. The topics share in common that they represent complex ideas and situations which we may find interesting, but difficult to understand and interpret. While there are many theories to help us understand the particular in physics, astronomy, etc..., there are few to help us understand the general, the whole. Biology and ecology, macro-economics and non-linear dynamics venture into these regions, and provide insights in so doing.



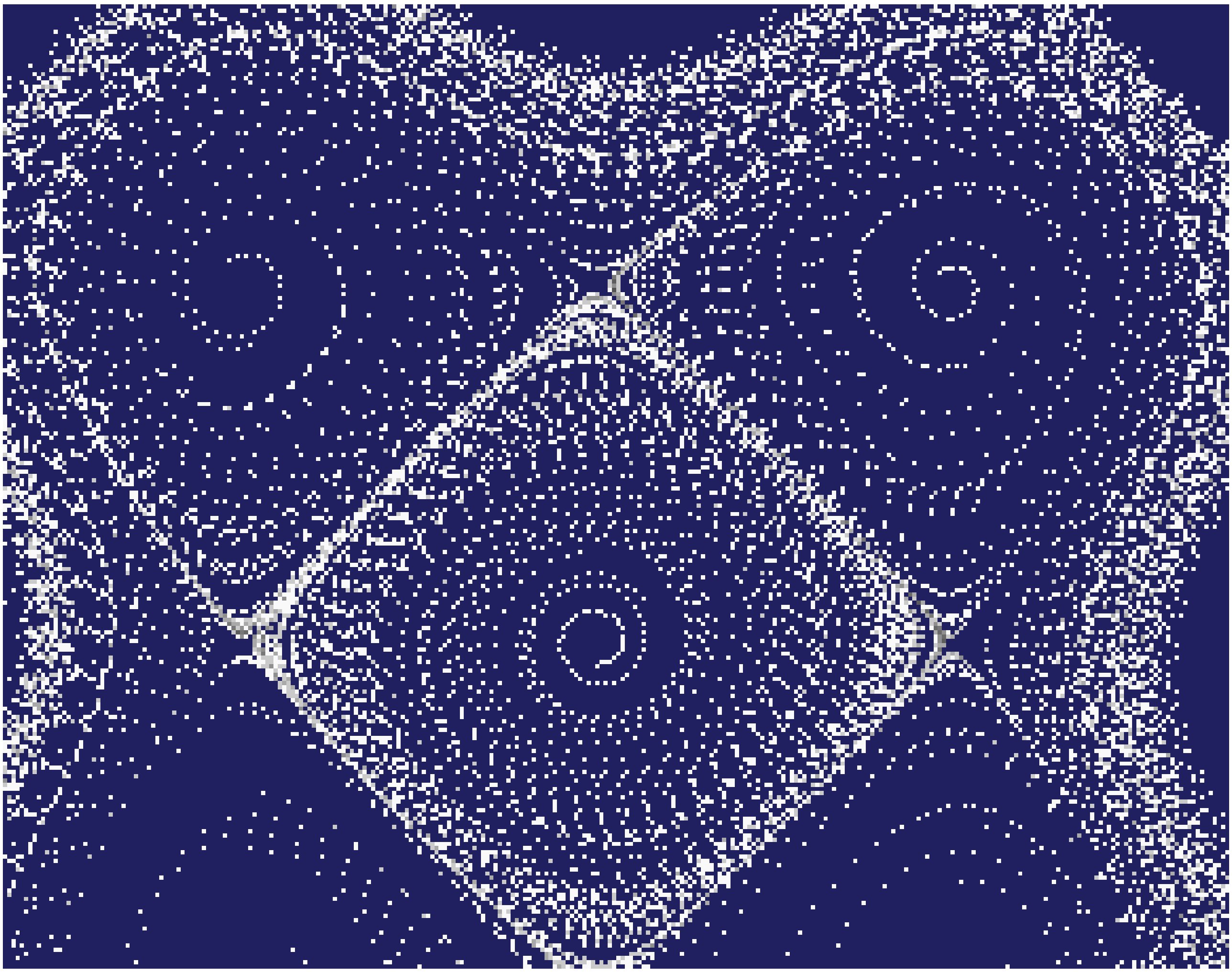
Fractal 13: Tunnel

At present, the West is still heavily caught up in Descartes reductionism. We see this philosophy in our schools, accounting, management, engineering and science, politics, social organization, etc. It gives us knowledge. But does it give us understanding? A visitor from another planet could gain knowledge about a clock, simply by taking it apart and seeing how it worked. That visitor might never understand the concept of time. Understanding comes from synthesis, from building up rather than breaking down, from looking outwards rather than inwards, from synergy rather than separation. A recent theory about the pyramids by the River Nile likened them to the Orion constellation and the Milky Way. That notion arose by looking outwards/upwards from the pyramids, not by looking inside them.

The theory of complexity, then considers the world without pulling it apart. Dismantling a clock is easier than, say, experimenting with a prison during a riot — in the real world, scientific experiment is often denied for very practical reasons. The theory is one of hope for continuance, for improvement, rather than a theory of eventual decay, like the second law of thermodynamics. The theory does not predict the future, except in the senses of trends and continual recycling, but it might enable us to understand today and to influence our tomorrow. The search for a theory of everything is a noble venture and deserves to succeed. The theory of complexity might, just might, turn out to be more useful in everyday life.

References

- Hitchins, D. K., 1992, Putting Systems to Work, John Wiley and Sons, Chichester, UK
- Hitchins, D. K., A Unified Systems Hypothesis, Systems Practice, December 1993, Plenum Press, New York.
- Kast, F. E. and Rosenzweig, J. E., (1972) The Modern View: a Systems Approach, in Open University Systems Behaviour, pp. 44-58
- Lauwerier, H., 1991, Fractals, Images of Chaos, Penguin Books
- Lotka, A. J., 1922, Contribution to the Energetics of Evolution, Proc. Natl. Acad. Sci., 8, 147-155
- Miller, George A., 1956, "The Magical Number Seven", Problems of Perception, The Psychological Series, Harvard Vol. 63, No. 2
- Odum, Howard T., 1971, Environment, Power and Society, Wiley Interscience, New York
- Romer, J., 1988, Testament, Michael O’Mara Books Ltd., London
- Romme, W. H. and Despain, D. G., 1989, The Yellowstone Fires, Scientific American, 261 (5)
- Ruthen, R., 1993, Adapting to Complexity, Scientific American, 268 (1), pp110-117
- Sanders, H. L., 1968, Marine Benthic Diversity, American Naturalist, 102, pp 243-282
- Senge, P. M., 1990, The Fifth Discipline, Century Business, London, UK



Fractal 14: Spirals.

Command & control

Decision making

Understanding how military groups make decisions is obviously important; it can cost lives to one side or the other, or both. As such, it is a legitimate and indeed important subject for study.

Surprisingly, how we humans make decisions is remarkably poorly understood. Exploring how the military approach the issue in relatively well-defined situations which they have, in the past, faced might help us understand how things work — or don't work! And, perhaps, we can apply any new knowledge to less extreme situations! A sort of intellectual "swords into plough shares"!

The nature of decisions

Decision:

> "...a choice between options…"

- Utility theory proposes that we make decisions to maximize utility or usefulness.
- Statistical, catastrophe and chaos theories indicate future may be predictable/unpredictable as weather.
  - Long-term stable but short-term unstable, according to climate.
- How can we choose between options in dynamic situations if the future is unknowable?
- Can we/should we avoid making decisions if the future is unknowable?

How do we go about making decisions anyway?

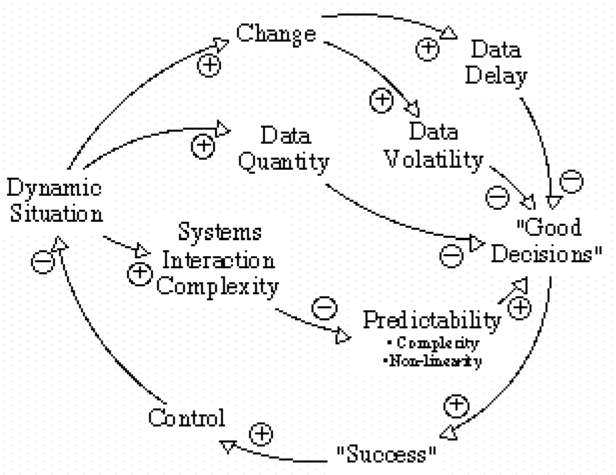
Decision-makers biases

It seems that humans, complex as ever, are prey to a wide variety of behavioural influences and pressures when they make decisions. Ian White has identified some of the biases which affect decisions:

- **Adjustment & Anchoring.** Decision maker selects a datum and fits other data to it improperly.
- **Availability.** Uses only freely-available data. An event is believed to occur frequently if it is easy to recall similar events.
- **Conservatism.** Failure to revise estimates as frequently as necessary.

- **Data saturation.** Reaching premature decisions on too small a sample and then ignoring further data.
- **Self-fulfilling prophecy.** Values certain outcomes and acquires and analyses only data that supports that outcome.
- **Attribution error.** Associates success with inherent personal ability and failure with bad luck. "When you are wrong, you screwed up, when I'm wrong it was just bad luck".
- **Gambler's fallacy.** Assumes the occurrence of one set of events enhances the probability of an event that has not yet occurred. "I have smoked for 10 years without getting cancer&endash;clearly I am immune, so I can go on smoking.
- **Habit.** Familiarity with one rule results in its excessive use.
- **Law of small numbers.** Confidence in predictions based on small samples with non-discomforting evidence, than in predictions based on large samples with discomforting evidence.
- **Order effects.** Order of information presentation affects retention and weighting.
- **Outcome irrelevant learning.** Use of an inferior rule leads to belief in results because of inability to evaluate choices not selected.
- **Panic.** Under stress, facing many options which cannot be evaluated, either selects at random or fails to act at all.

What is a "good" decision?



The causal loop model above shows the dilemma of judging whether a decision can be deemed good or not. It really all depends on your viewpoint. You can take either of two viewpoints:

1. A decision is "good" if the decision maker has taken account of all the relevant data, has weighed up the pros and cons, and has developed a balanced judgment.
2. A decision is "good" of the out-turn is that which the decision-maker intended.

For instance, is a good gun one made of the best metals, finely made, with a well machined bore and a smooth, well-oiled breech?

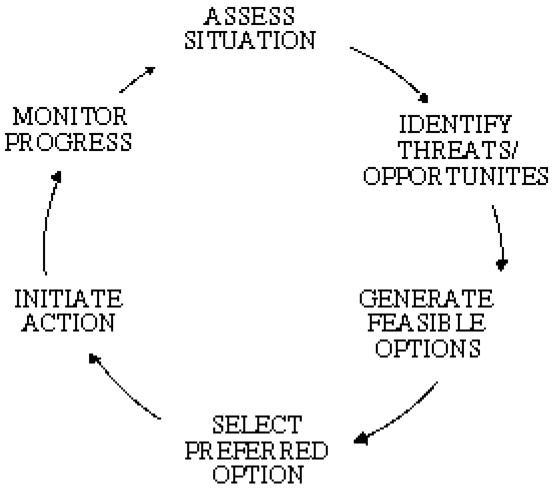
OR

Is a good gun one which puts the shell on the target?

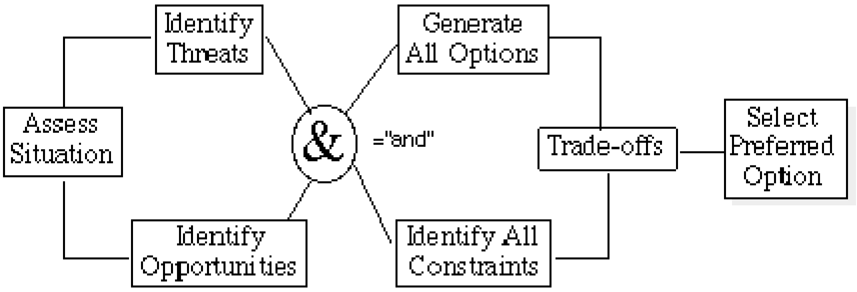
Put more succinctly, is the quality of a decision in the process or in the outcome?

For my part, I have to fall down on the side of outcome. However, the current paradigm in Command & Control thinking centres on process.

The C2 decision circle



Classically, decisions are reached by a repeated sequential process, shown above. Start at assess situation, and follow the arrows. Since the Action taken changes the situation, assess situation is necessary after the change, and so the process continues ad infinitum.



Another way of looking at this process, one which omits the cyclic nature, is shown above. This model is employed in:

- The estimate-a formal decision-making process in wide use by various militaries around the world.
- Systems engineering.
- Current C2 systems technology.

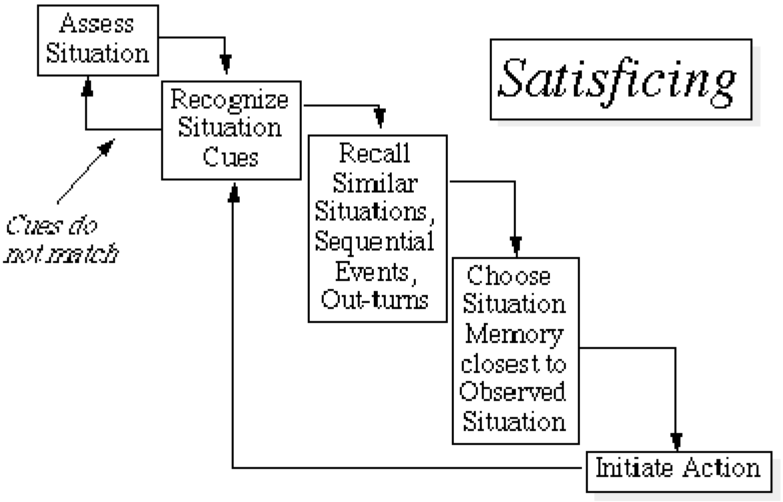
Satisficing

The process shown above has a distinguishing characteristic. The decision-maker(s) try to consider all the possible options, and to trade-off between them in order to find the preferred option. While this might seem logical, it is not necessarily how human's evolved to make decisions under pressure.

For instance, who considers all the options when the tiger is only five steps behind you?

We evolved an innately-human ability to make fast decisions under fight-or-flight pressures. If we had not, we would not have evolved as a species. Under such conditions, we do not consider and weigh up all the options — that would be naive. Instead, we use our experience of what has worked before in similar situations. We might mentally generate options, but we will stop doing so as soon as we identify and option that will serve the purpose. At that point we will go with the selected option.

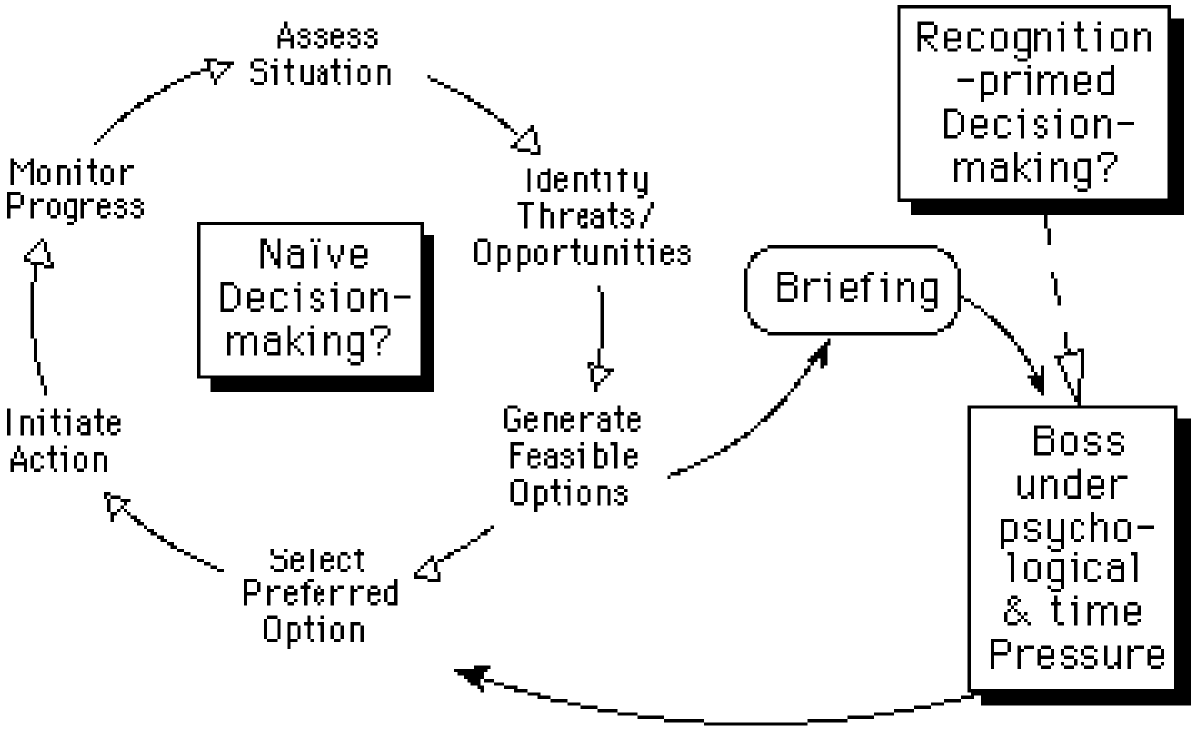
This process is called "satisficing".


Assess Situation
Recognize Situation Cues
Recall Similar Situations, Sequential Events, Out-turns
Choose Situation Memory closest to Observed Situation
Initiate Action
Cues do not match
Satisficing

The figure shows satisficing. Note the iteration indicated by the feedback from "initiate" to "recognize situation cues". The initial satisficing decision might have been wide of the mark, even for an expert decision-maker — he or she may have read the cues wrong. However, this is a cyclic process. As the action unfolds, the decision-maker has expectations which can be verified by the merging cues. If the cues are as expected, fine. If, on the other hand, the cues are out of line with expectations, then the expert decision-maker will re-evaluate the situation and satisfice again.

So, satisficing is a decision-making process employed instinctively by an expert under time pressure, and it "homes in" on a final solution (as opposed to making a "big-bang" "this is the only way" choice and sticking to it in the face of mounting contrary evidence).

Decision paradigm clash


Assess Situation
Identify Threats/ Opportunities
Generate Feasible Options
Select Preferred Option
Initiate Action
Monitor Progress
Naïve Decision-making?
Recognition-primed Decision-making?
Briefing
Boss under psycho-logical & time Pressure

On occasions, these two styles of decision-making can come into conflict, as shown above.

- At left, naive decision-making might be undertaken by a group of staff officers in an HQ, and they might take anything up to 24 hours or more to go round the circle — referred to as the planning cycle.
- At right, the "boss" is briefed, sometimes using CCTV, so placing him or her under psychological pressure to make on-the-spot decisions in full view of many subordinates. The boss is, therefore, likely to "satisfice" or employ Recognition-primed Decision-making as Gary Klein calls it.

- The result?
  - Disagreement, of course.
  - The boss, using his experience may reject the advice of the staffs and select a particular course of action. the boss probably also decides that his staff are not doing too well.
  - The staff, having spent 24 intensive hours coming up with a recommendation, feel rejected and undervalued.
- These military situations would find their counterparts in boardrooms around the country, with MDs and CEOs corresponding to bosses.

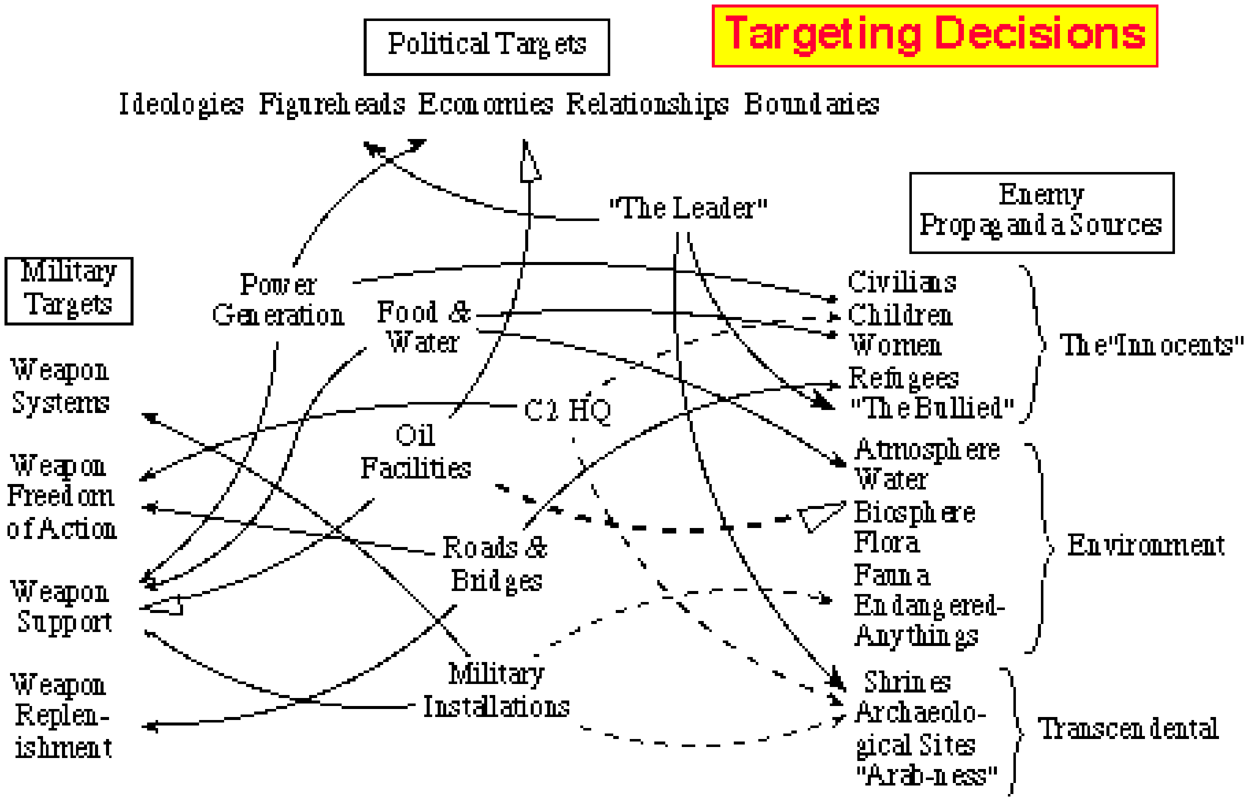
Decisions and synthetic environments

- Great potential.
  - Until now, C2 systems designed by engineers to meet what they believe are operators needs.
  - Operators not sure what they need, unable to describe it effectively in writing, engineers have different viewpoint...
- C2 technology based on naive decision-making model.
  - Slow, methodical, comprehensive, predictable, uninspired.
  - Each process supported by technology as though it were alone.
  - I.e. no concept of system, team or learning in the design.
- SE/VR. (Virtual reality)
  - New concept.
  - Engineers create SE within which operators may form teams, employ synthetic "technology", tackle variety of situations.
- Result. Operators:
  - a) Design own, team-based systems.
  - b) Develop/train cohesive operational team.

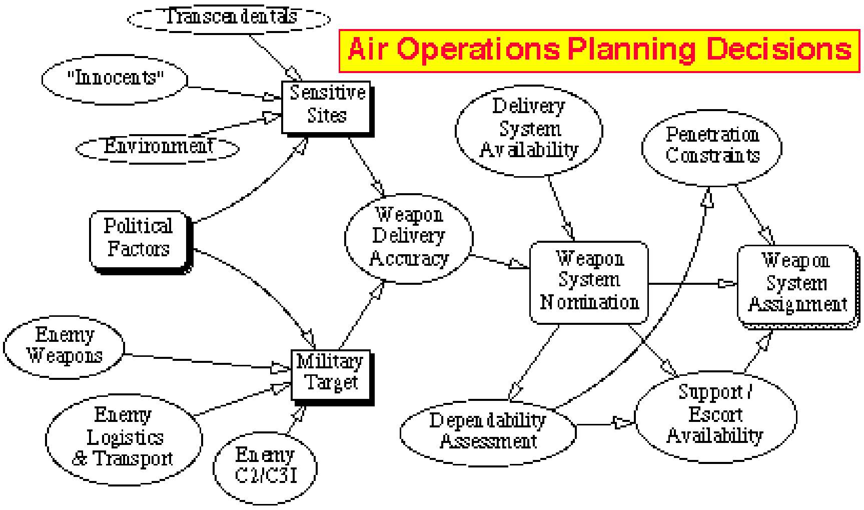
Decision-making — man or machine?

- For set-pieces, prescribed decisions are feasible:

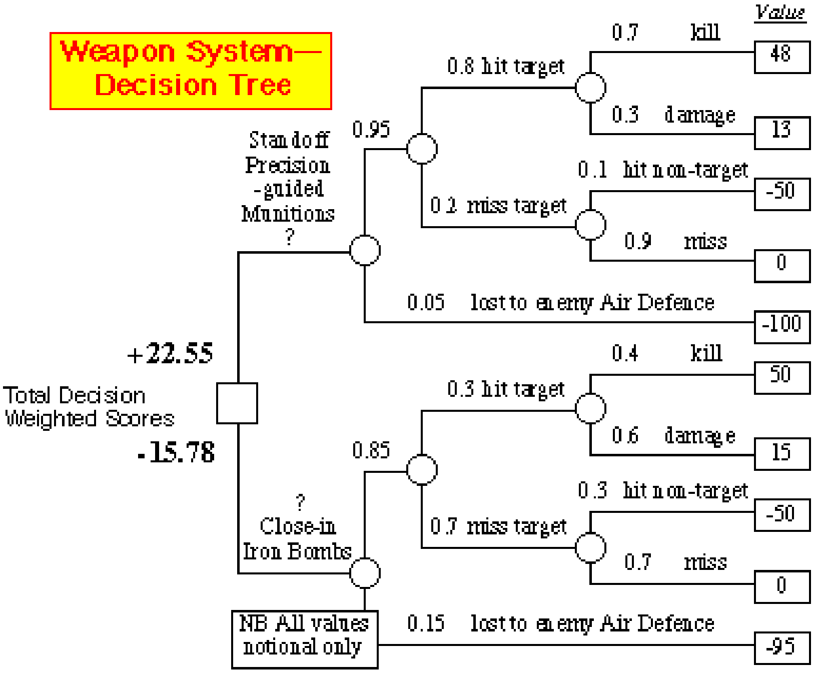
  - Area air defence, known incoming weapon systems.
  - Saturation bombing, non-retaliating enemy.
- In volatile situations, short time horizons of predictability:
  - Chain from cause to effect unclear.
  - Less amenable to machine decision.
- In the following 3 examples, all derived from, or based on, newspaper accounts of Desert Storm, are decisions best suited to man or machine (i.e. software algorithm)?



This diagram shows how different parties to a conflict might represent the same potential target. So, a military target of Roads and Bridges might be intended to deny the enemy freedom of action and/or weapon replenishment. Enemy propaganda could easily, even perhaps justifiably, represent attacks on Roads and Bridges as an attack on refugees, bullied innocents who would be unable to flee the conflict. With CNN listening for every opportunity, that sort of propaganda can wreak havoc with military strategies and tactics.



This figure shows how military planners might try to reconcile the issue of politically, or environmentally, sensitive sites which are also military targets. In particular the approach might consider the employment of precision weapons with little or no collateral damage risk.



Finally, in this group of three, we have a classic decision tree. This one compares the value of standoff Precision Guided Munitions (PGMs) i.e. laser-guided bombs launched at a distance, with old-style iron bombs delivered from close to the target. The comparison starts with establishing a comparative outcome measure in the right hand column of boxes.

- For instance, the worst outcome, -100, arises when a PGM equipped aircraft is lost having failed to reach the target. This is a total lose-lose of an expensive asset.
- The next worst outcome, -95 is for an iron bomb aircraft lost to enemy fire. This is also lose-lose, but of a less expensive asset — hence the slightly better score.
- The top score, 50, is for a successful attack by an iron-bomb - win-win using the cheapest weapon.

In this simple example, for which I made up the numbers of course, the outcome is strongly in favour of standoff PGMs — surprise! (What use is a complex method of “deciding” what you already knew? and, on what basis would you select the numbers to put in the right-hand column boxes?))

So, have you made your choice?

- Which of the three decision-making methods is best suited to humans, and which to machines?
- Come to that which, if any, is valuable, or would you rate them suspect?

And that is one of the main issues with decision-methods:

- Individuals and groups make decisions differently.
- Experts make decisions differently from naive beginners.
- Experts make decisions in different ways according to the urgency.
- Experts under pressure "satisfice".
- Homo sapiens evolved by satisficing&endash;remember, who trades off options when the tiger is five steps behind?

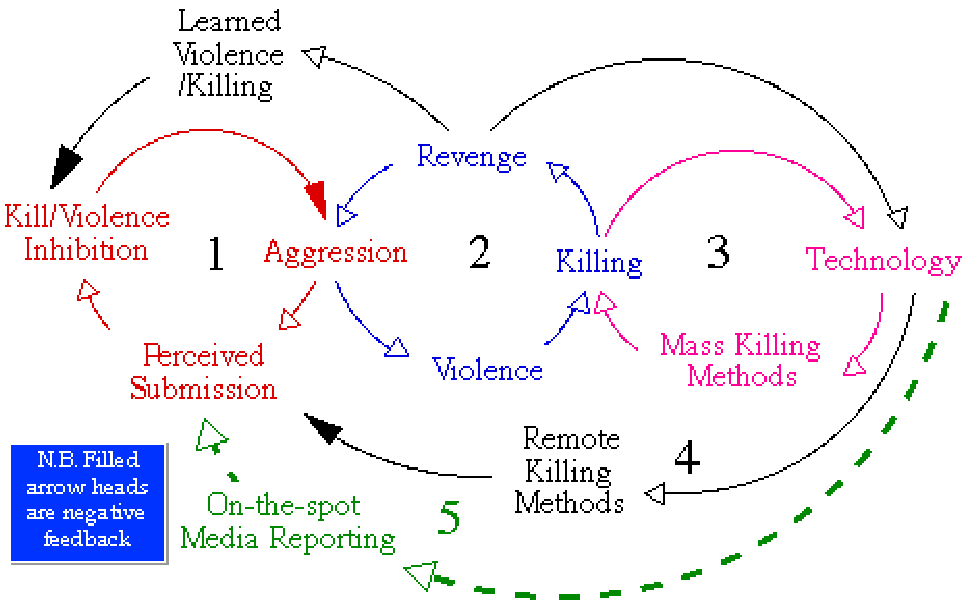
> “We do not understand yet how we comprehend and make decisions...”

Conflict management

Human behaviour

Some view killing as an inevitable consequence of human behaviour. It seems likely that humans have a kill inhibition just as most other animals, for humans, there are two problems:

1. We have developed methods of killing remotely.
2. We learn to overcome the inhibition.



The figure uses the methods of system thinking to show the effects of technology and remote killing on our behaviour. it also shows the effect of different technology, communications and TV, in restoring our visibility of submission. As in so many cases, the technology that creates the problem may offer some solution, too.

What's It about?

Command & Control (C2 for short) is about the management of conflict. Actually, business management can be about the same thing at times, but C2 has connotations of extreme force either applied, or in reserve.

A naive reporter once asked General Schwarzkopf what it felt like to orchestrate Desert Storm.

> "Orchestrated? You start conducting and then some son-of-a-bitch climbs out of the orchestra stalls and comes after you with a bayonet!"
> — General Norman Schwarzkopf

Is command & control, in extremis, controlled aggression through fear, while excess testosterone and adrenalin make the legs tremble and the palms sweat?

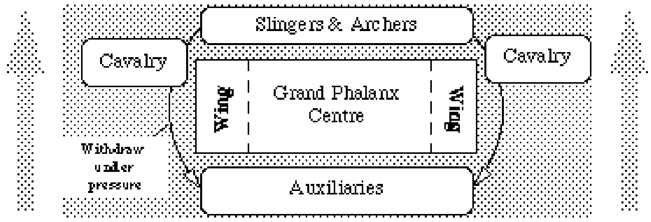
Command in history

- **Sumerian Phalanx**. 4th millennium BC, 6-man deep, shields, pikes, battleaxes
- **Egyptian Square**. 2nd millennium BC, 100-man deep, copper battleaxes, bows, quivers for volley fire, wings and centre, flanking movements, recruit training, cadence step.
- **Assyria**, 9th Century BC, 120,000-man army, archers, mounted lancers. Archers mounted for mobility, fought on foot in pairs - one for bow, second for wicker shield. Engineer corps
- **Greek Phalanx**, 7th Century BC, 8-man deep files, 8-ft pikes, 2-foot swords, centre & wings, advanced to flute.
- **Roman Legion**, 4th Century BC, 120-man maniples, throwing spears, checkerboard formation.

Alexander

Syntagma } 16x16 men. Front five ranks held 21ft spears. Remaining 11 ranks held spears vertically or resting on shoulders of men in front

4 x Syntagma = Chiliarchia
4 x Chiliarchiae = Grand Phalanx



- Muslims, 7th Century AD, religious fanaticism.
  - "The sword is the key to Heaven and Hell" — Koran.
  - Mail and helmets, but no shields, brute force rather than tactics, sword, javelin, dagger, bow, scimitar, mounted lances.
  - Employed Europeans as mercenaries for phalanx operations.
- Mongols, 13th Century:

    - Cavalry, 1 touman = 10,000 horsemen, 1 army = 3 toumans.
    - Battle regulated by black and white flags — no oral or written orders.
    - Cavalry in five lines:
        - First two wore leather armour, used sabres and lances.
        - Following 3 lines — bows and javelins, unarmoured.
- Europe, 14th Century:
    - Crecy, long-bowmen vs French knights.
    - End of 1000 years of mobility-by-cavalry — sacrificed for firepower.
- Swiss Phalanx, Spanish Square — 50-man front and per file.

And so to Napoleon and modern times, infantry, tanks helicopter-cavalry...

Throughout this time, and today, command is limited by the abilities of the force to respond as much as by any C2 technology.

What makes an effective fighting force?

Examples of effective C2 abound in History:

- The ability of Alexander to sense tentativeness or outright fear among the troops at a certain point in the enemy lines and to exploit it with a rapid thrust there.
- Caesar's care never to lose "control" of his legions so that, when a battle was going badly, he could disengage before tactical set-back turned into catastrophe
- Wellington's skill in anticipating the thrust of the enemy's attack and manoeuvring laterally in time to avoid it

Johnson & Levis, Science of Command & Control

Expectations of command and control

- **Force commander:** Intelligence, decision support, execution management, and deployment management.
- **Out-of-area commander:** Focus for command information and centre for control.
- **Political Master:** Political situation control.

- **National MOD:** Application of national MOD influence.
- **Procurement financier:** Force multiplier to reduce overall defence costs.
- **Lateral force commander:** Intelligence source, coordinating agent, resource source, and synergy management.
- **Subordinate commander:** Control and reporting (C&R) authority, mission source, and resource source.
- **Journalist:** Source of up-to-the-minute information for public consumption.

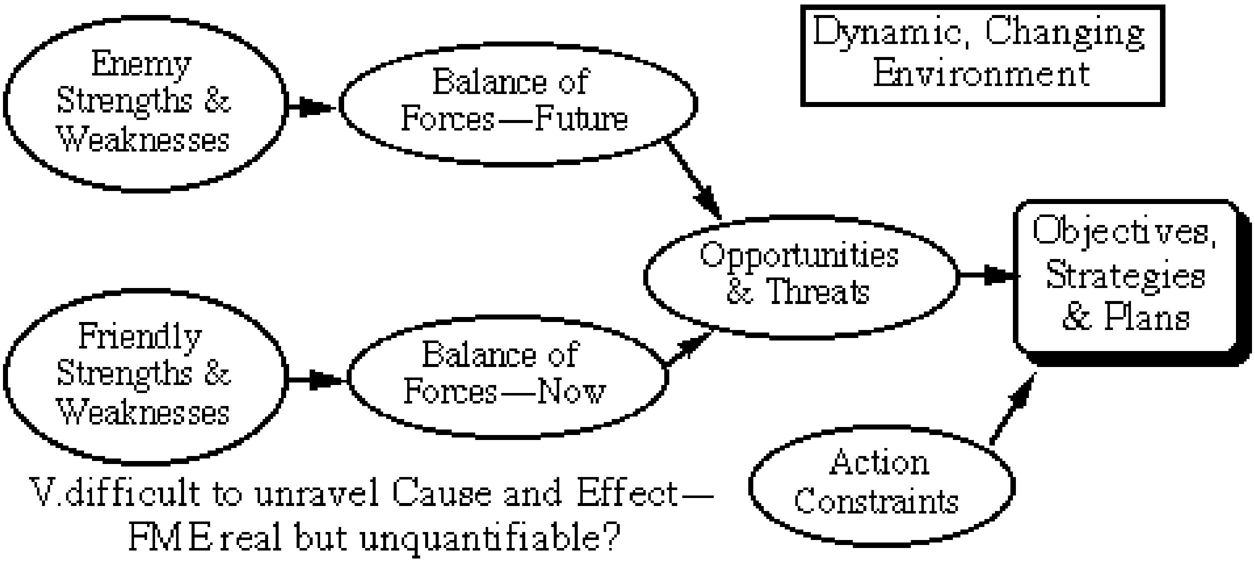
A view of the defensive C2 task

In practical terms, the defensive C2 task is to coordinate the defensive assets so as to:

- Deter ¥ Counter aggression ¥ Face a changing Threat Direction ¥ Counter Diverse Threat Elements ¥ Protect own Latent Offensive Forces ¥ Distinguish Friend from Foe, esp. own Returning Offensive Forces.
- Survive ¥ Avoid Detection ¥ Prevent Interception / Exploitation ¥ Defend Defensive Assets ¥ Defend own C2 ¥ Tolerate Damage&endash;redundancy, reconfiguration.
- Be available ¥ Reliable ¥ Dependable ¥ Maintainable ¥ Transportable ¥ Mobile.
- Win the Cost-Exchange Ratio Battle&endash;cost of Defence should not cost more than the Assets so saved, in the long term.

Command and control and "force multiplier effect"

Force multiplier effect is a term used to describe the ability to make more out of your own forces than you might expect. It is a much-abused, much misunderstood term.


Enemy Strengths & Weaknesses
Balance of Forces—Future
Dynamic, Changing Environment
Opportunities & Threats
Objectives, Strategies & Plans
Friendly Strengths & Weaknesses
Balance of Forces—Now
Action Constraints
V.difficult to unravel Cause and Effect—
FME real but unquantifiable?

The command and control (C2) design issue

Knowing that:

- War is generally chaotic.
- Any future war will be a dynamic patchwork, not a series of set pieces.

The task is to:

- design a human-centred decision — support system for:
    - an unknown rôle, in...
    - an unknown situation...
    - in an unknown area...
- to address an unknown opponent, or...
- police an alien culture.

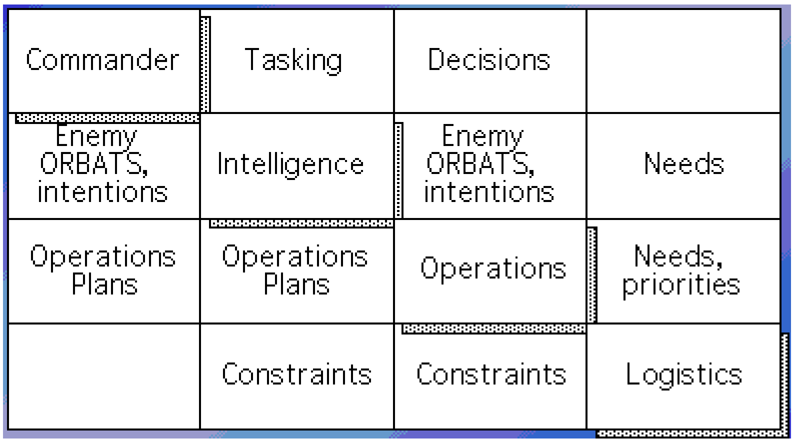
Viewpoints

- **Deterministic**
    - C2 is generic, therefore...
    - laws govern the design of CIS
- **Human**
    - enemy and environment make situations unpredictable, therefore...

  - only human ingenuity, synergy, training, reactivity can cope.
- **Non-linear dynamical**
  - real world is made from open, interacting systems, behaving chaotically, therefore...
  - we must learn to design adaptive systems without clear boundaries.

Generic C2 N2

C2 can be described, crudely, in a generic way as follows:



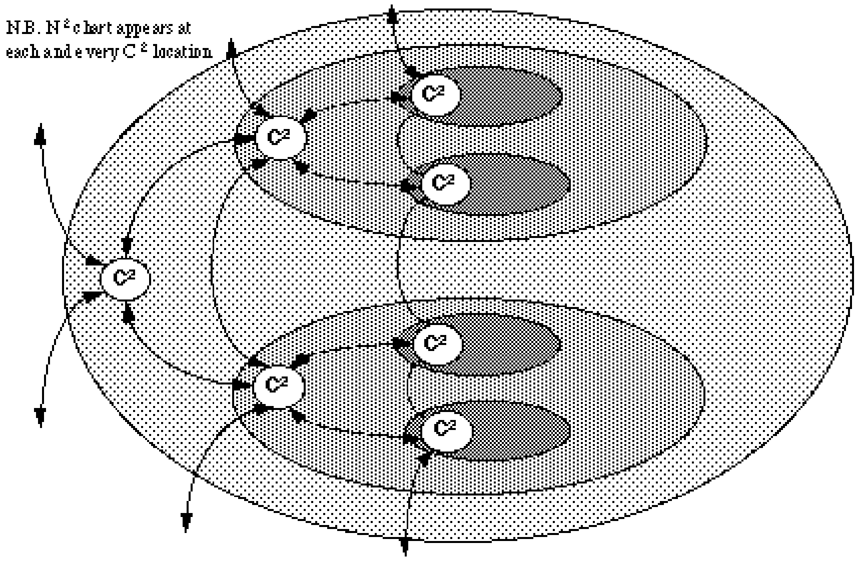
Commander	Tasking	Decisions	
Enemy ORBATS, intentions	Intelligence	Enemy ORBATS, intentions	Needs
Operations Plans	Operations Plans	Operations	Needs, priorities
	Constraints	Constraints	Logistics

The N-squared (N2) chart show the basic roles (commander, intelligence, operations, logistics) and the information that they interchange. So, in the N2 chart:

- Commander gives decisions to operations.
- Logistics gives constraints to intelligence.

Fractal C2

The N2 chart above represents generically the activities at each of the circles containing C2. the whole diagram represents a nesting hierarchical organization. In army terms,



- The outer ellipse might be a corps.
- Next two inner ellipses might be divisions.
- Smallest 4 ellipses might be battle groups.
- And so on…

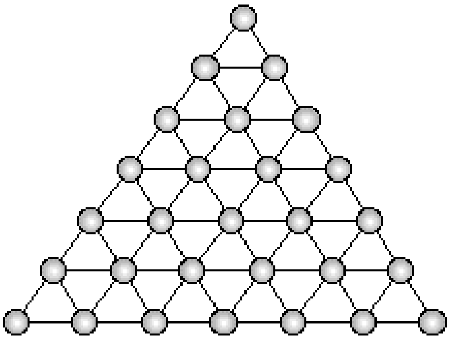
While it would be imprecise to insist that the structure in the figure is strictly fractal, there is evidently a degree of self-similarity at each hierarchy level.

Deterministic viewpoint

In attempting to penetrate the mysteries of C2, I developed an analytic approach based on a created mathematics of pyramid hierarchies.

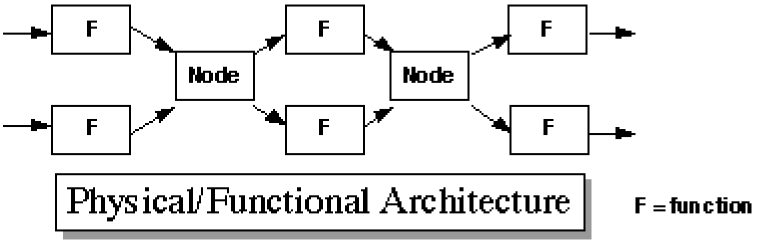
Pyramid laws

- **C2 Law of diminishing lateral communication:** We know in practice that it is harder to get agreement with someone who is more distant laterally in the hierarchy, i.e. you have to go higher up the pyramid to find a common boss.
- **C2 Law of vertical data compression:**
  - Each of us has roughly the same brainpower — a so-called Crapper's Brainful (after Sir Thomas Crapper, inventor of the flush toilet).
  - So, if you have, say, five subordinates in the pyramid, and you all have the same brainpower, then you can interact and capture only one fifth of their information effectively.
  - As you go up the tree, data gets compressed at something like the span of control (= pyramid slope) at each level.



- **Decision rate invariance** — see below.
- **Infrastructure** is minimized by symmetrical partitioning.

C2 Survivability



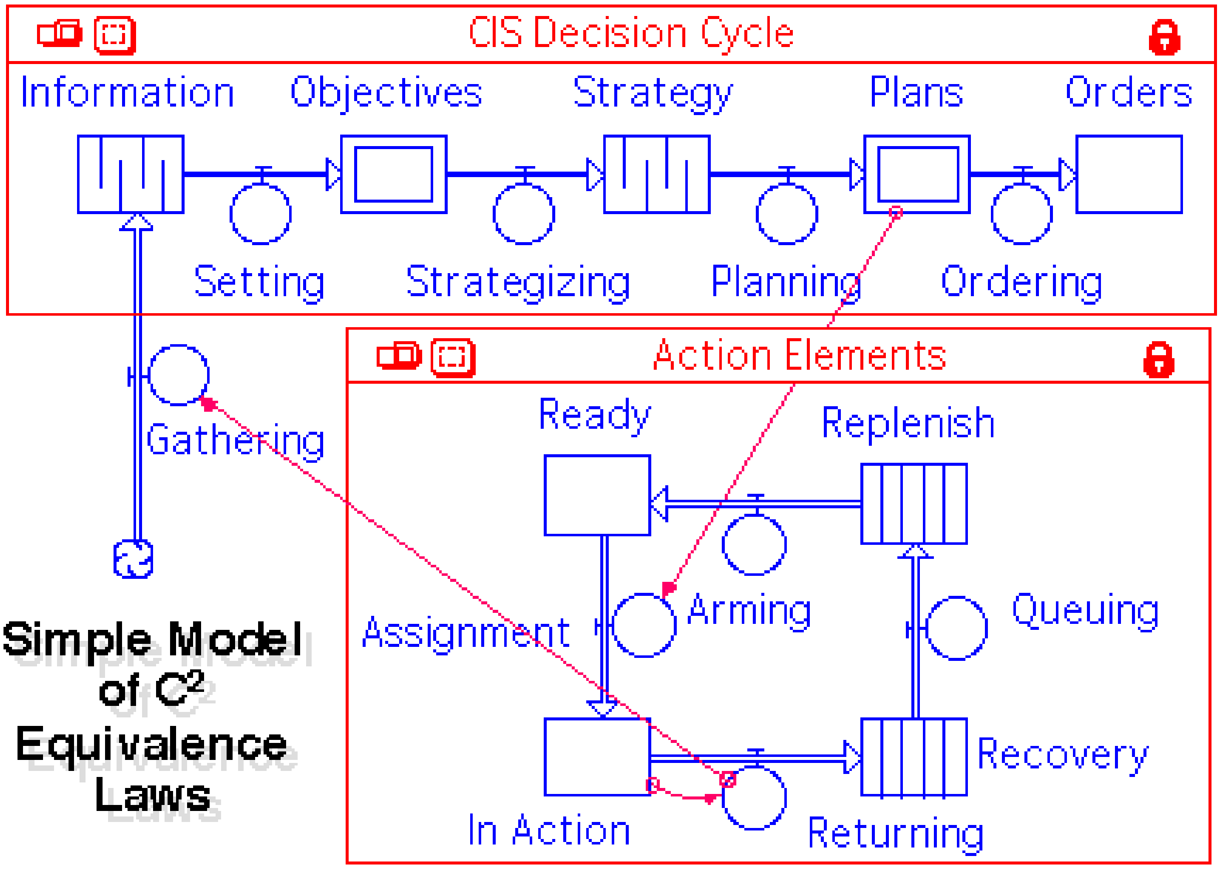
- Functional survivability is inverse to the number of singular functional architecture nodes, and to the degree of their exposure.

Equivalence laws

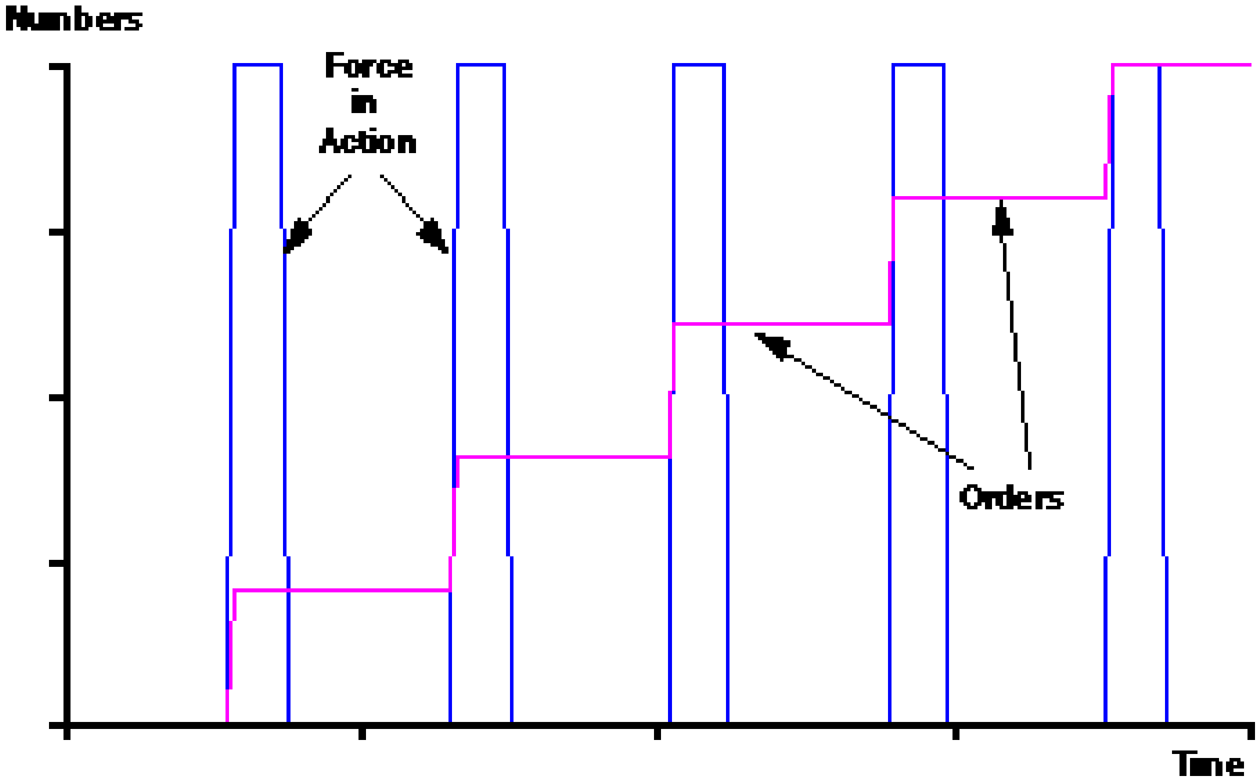
The theory suggests as follows:

- Mean rate of issuing C2 order-sets is proportional to the mean rate of action element turnaround.
- Mean rate of Intelligence reporting is proportional to the mean rate of action element turnaround.

To test the theory, I developed the following simple dynamic model:

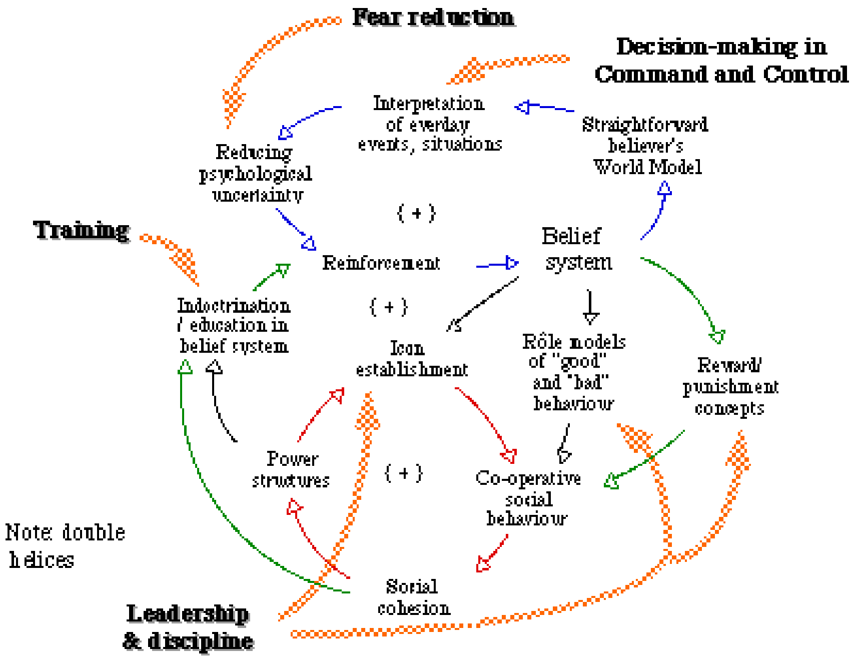


The top half of the model shows the command decision cycle, with information being used to develop objectives strategies, plans and orders. See the GRM; mission management for further explanation. The lower half shows a force in various states: ready, in action, etc. The Laws emerge because of the cyclic behaviour of the action elements. Once they have been in action, they return and are replenished (perhaps repaired) before being ready to go again. Giving the action elements orders more frequently cannot result in those orders being implemented, because the force is temporarily unavailable. Similarly, the rate of Intelligence reporting coincides with the action frequency — no action, no intelligence to report.



The graph shows the results of running the model. At each step in the magenta line representing orders sent, the force undertakes actions and then recovers. The fastest that orders can be sent (sensibly, that is) is that action element turnaround cycle.

Human viewpoint

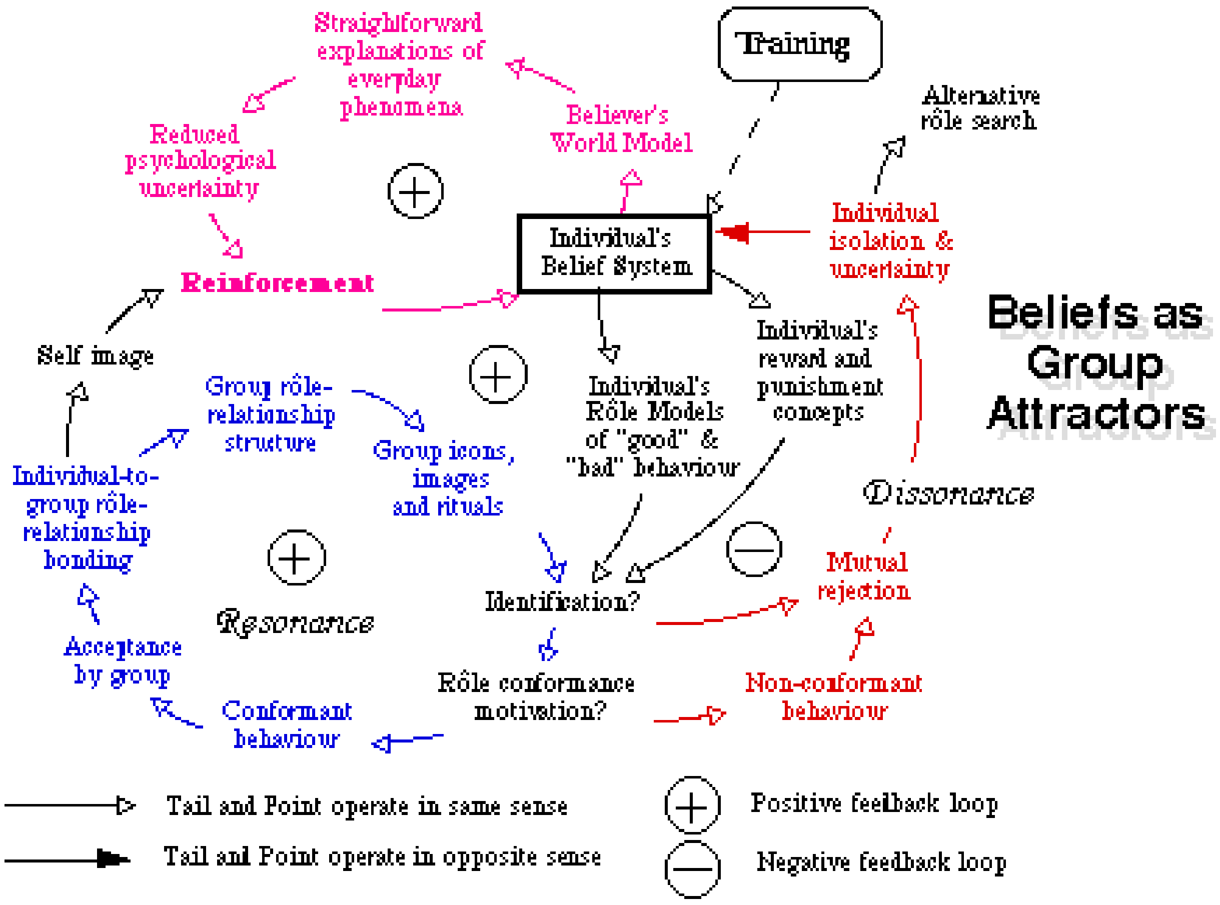


An understanding of mission management and behaviour management in the C2 context can be gained from systems models. The following figure shows the way in which belief takes a central role in command and control.

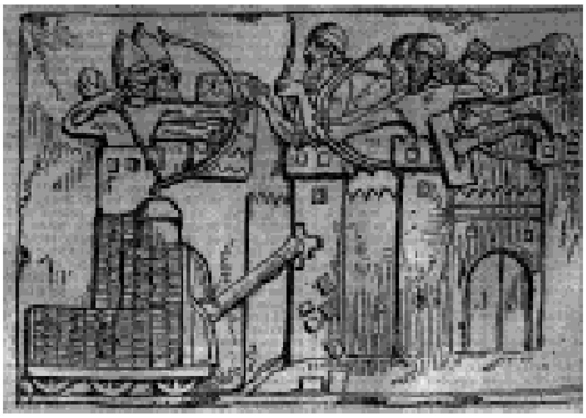
Ignoring the brown arrows, figure above, for the moment, we can see three interlocking loops.

- The top loop is about the individual. Beliefs give him or her a straightforward view of the world, offering simple, comfortable explanations of everyday events and phenomena. This reduces psychological uncertainty, so reinforcing the beliefs, simply "because they work".
- Beliefs generate role models of "good" and "bad" behaviour, where these terms are relative.
- These in turn promote conformant behaviour, generating social cohesion, the development of power structures, etc..., as the figure shows.
- Power structures enable formal education to be established, which will generally reinforce the beliefs which enabled it to emerge in the first place.
- Icons form a vital coordinating focus. Icons may be people, or things — charismatic generals, regimental colours, etc...

The brown arrows show how military ideas map on to a map which is essentially generic.

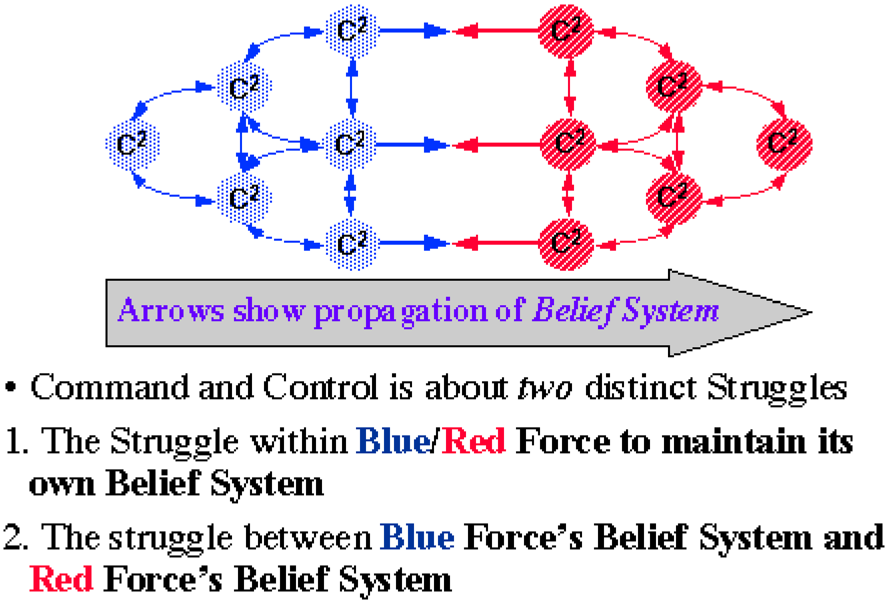

Straightforward explanations of everyday phenomena
Training
Believer's World Model
Alternative rôle search
Reduced psychological uncertainty
+
Individual's Belief System
Individual isolation & uncertainty
Reinforcement
Beliefs as Group Attractors
Self image
Group rôle-relationship structure
+
Individual's reward and punishment concepts
Individual's Rôle Models of "good" & "bad" behaviour
Group icons, images and rituals
Individual-to-group rôle-relationship bonding
Dissonance
+
−
Mutual rejection
Identification?
Resonance
Acceptance by group
Rôle conformance motivation?
Non-conformant behaviour
Conformant behaviour
Tail and Point operate in same sense
+
Positive feedback loop
Tail and Point operate in opposite sense
−
Negative feedback loop

A variation on the previous model shows the top lop to be the same. This model shows, however, how individuals fare when seeking to join a group. They find themselves either resonating sympathetically with the ideals of the group, or antipathetic and dissonant with those ideals. In the latter case, we should expect the individual to find another group to which to belong.



It is surprising what you can find in old Bibles. The figure above shows the Assyrians attacking a fort about 880BC. they are using a mobile battering ram to breach the garrison walls. Lulls during such events occasionally saw the garrison commander throwing food and wine over the battlements for the enemy. This appears to have been early psychological warfare: "do your worst, we have plenty of provisions and are rather enjoying ourselves".

In summary, then:



- Command and Control is about *two* distinct Struggles

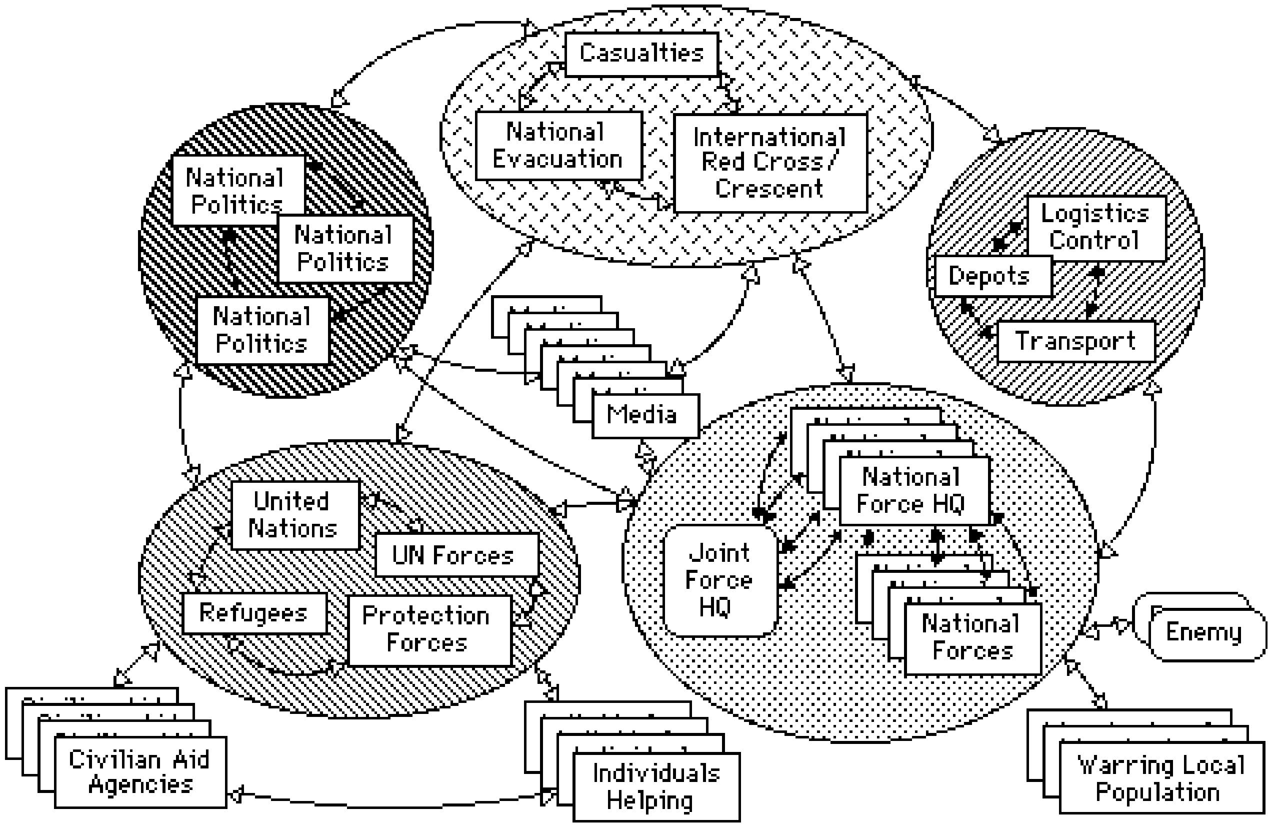
1. The Struggle within **Blue**/**Red** **Force to maintain its own Belief System**
2. The struggle between **Blue** **Force's Belief System and** **Red** **Force's Belief System**

Non-linear dynamic viewpoint

The third viewpoint is so difficult to accept that many pretend it does not exist. But, the facts are there:

- We cannot know the future.
- The world s generally chaotic, especially on the edge of conflict.
- Linear predictive views are untenable.
    - We do not know what is going to happen.

- We do not know what the enemy will do.
- Any decisions we make must be intelligent guesses at best.



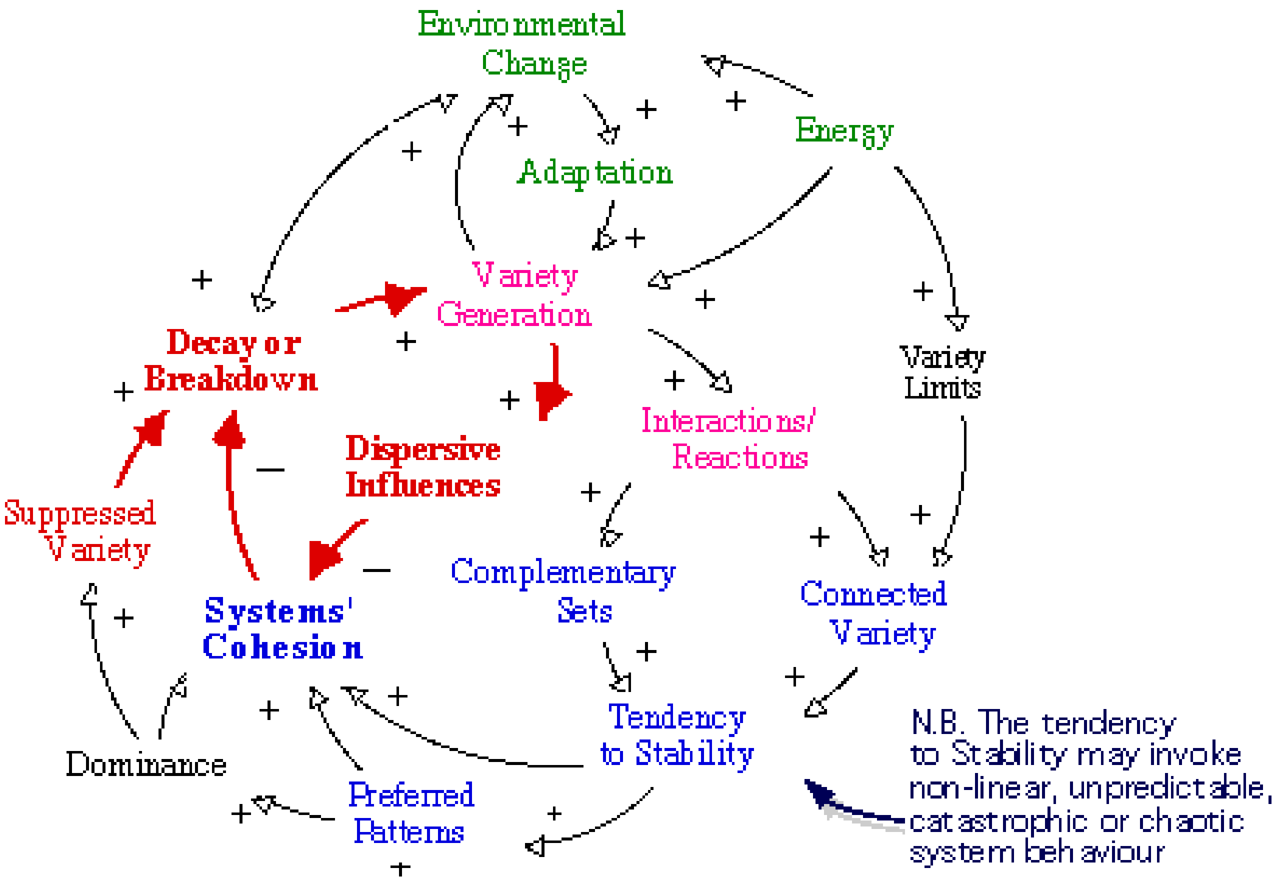
The figure shows one view of the kind of messy architecture one might get in a peacekeeping assignment such as Bosnia in the former Yugoslavia. In fact, the real situation is much more complex, since each of the neat ellipses and rectangles would be spread out across the geography of the country concerned, all mutually overlaid, intertwined and entangled.

Complex systems like this are not designed — they happen. And, unlike neat linear systems, there is no beginning and no end. Instead it is all tangled loops.

So, in such situations how can one cope? Or, can one cope at all?

Unified systems hypothesis — Map

One approach is to develop a much more open way of addressing complex system issues. I have developed the unified systems hypothesis (USH) to deal with such problems.



The USH Map integrates a number of simple principles into one powerful causal loop. Key to understanding is that Variety is viewed as a commodity, of which you can have more or less. Connected variety forms complementary sets, which create a stable network, resistant to change. This is represented in the map by systems cohesion. Dominance can arise, and has the effect of suppressing variety which leads eventually to decay and breakdown, and the cycle repeats.

It is possible to maintain cohesion by maintaining variety, i.e. by injecting new variety. It is possible to maintain cohesion with domination by maintaining variety, i.e. by stopping its suppression. it is possible to generate more variety by injecting more energy, top right of figure. Some of this new variety may connect, others may remain isolated and become dispersive variety, attempting to break down systems cohesion.

Using these ideas carefully results in a guide to designing non-linear systems to exist in a non-linear world — the one we actually live in!

Open system design guidelines

- **Step 1:** Establish CIS objectives and requirements by reference to containing system(s) (look outwards).

- **Step 2:** Establish sibling systems and their interactions to be perturbed by new/altered CIS.
- **Step 3:** Conceive complementary systems to neutralize unwanted perturbations.
- **Step 4:** Design CIS as an open system to complement siblings in contributing to containing systems' objectives (i.e. design outwards first).
- **Step 5:** Partition CIS, promoting internal connected variety, limiting dominance (then inwards).
- **Step 6:** Enhance SOI cohesives, diminish dispersives.
- **Step 7:** Interconnect the variety to promote sibling stability, mutual self-reward.

Viewpoint summary

- As many viewpoints as "experts"?
- C2 — linear, controlled, predictive system in chaotic, unpredictable, unknowable world?
- Predetermined C2/CIS solutions may apply to some situations (e.g. SDI, AD?)
- Some C2 can only be developed in operation.
    - Must connect with evolving range of alien systems.
    - E.g. peacekeeping/enforcing.
    - Conventional ethics, morals, methods, tools, techniques inapplicable.
- Are these really about technology?
- ...or, more about human talents for being smart and adaptable?

About cybernetic

History

The story that needs to be told about cybernetics if it is called to confront the challenges posed by a highly complex and sometimes unstable world, has its roots in the city of Athens in Greece.

350 years BC: this is the home of two of the greatest minds ever known. Plato and Aristotle used the word Keebernetes meaning the steersman of a ship and extended the use of the word to mean "the man in charge of a city" also know as the ruler then the word disappears to emerge again as kubernetes the Latin equivalent. For the next cybernetic milestone, we must travel in time from Athens to industrial Manchester about 2100 years later.

In 1788 the watt steam engine a cybernetic contraption becomes the most important technology of the Industrial Revolution.

Now we travel to Leon friends the year is 1834 Andre Marie ampere the French scientist borrow from the Greek language and coined the word cybernetic to identify the science of governing the state, therefore the preliminary impact of cybernetics is semantics; governor, government, and governance originated from kubernetes.

In broad terms cybernetics is the science of governance, the metaphor to go with it is a small boat piloted by its captain making adjustments to unforeseen the services, much in the same way as Odysseus is depicted in this drawing with a Cyclops hurling huge boulders and an effort to capsize it.

To find the best known and first formal definition of cybernetics, we have to travel to New York City where cybernetics was born you shown here is Norma beaner an American expert and a mathematician from MIT founding father of cybernetics; Norbert Weiner and other scientists were confronted with the problem of purposeful behavior just prior to and during World War II, back then scientists became aware that physics in spite of all its glamour did not have a solution or even a proper description of what was involved to produce life as it turned out cybernetics was a science that was able to explain purposeful behaviors.

According to Weiner one of the first scientists to focus his thinking on what later became CYBERNETICS was Arturo Rosenblueth, a Mexican physiologist doing researches on homeostasis with Walter Cannon at Harvard University In the late 1930's.

It was however until 1943 that Arturo Rosenblueth together with Norbert Weiner and Julian Bigelow producing a paper now quite famous in the history of cybernetics where they question the assumptions made by traditional science; purpose they assured could be built into a mechanism the key was to create a connection in the form of what we would now call an information loop where the output of the system is transferred back to the input and affects it in such a way that the mechanism will display gold getting properties.

While this paper was first presented publicly to a group of scientists among them Gregory Bateson Margaret Mead, and Warren McCulloch, the reaction was immediate. Warren McCulloch was researching neural networks and Margaret Mead and her husband were both social scientists, all three plus Frank Freeman Smith joined in to create the core group behind the idea of exploring causality, circularity feedback, and purpose.

However, the Macy group as it was called initially got together until World War two was over. The high-tech digital world we live in today is a direct result of what later became a sustained peacetime effort for some of the most brilliant minds of the past century came together and shared and confronted ideas to give birth to cybernetics.

John von Neumann another illustrious member of the Macy group while Neumann was a Hungarian mathematician among other things a developer of automation theory and co-author of game theory. it was during the second Macy conference in 1946 that John von Neumann presented the design for the very first general-purpose programmable computer the ENIAC, he also made comparisons between computer and brain. After the 1946 Macy conference in the New York Academy of Science later gave a keynote address in which he spoke of information which should be measured using base 2 algorithms. Information has the same formula as entropy said Wiener with a negative sign in front for readers and biographers.

This presentation marks the birth of the Information Age for the public at large feedback became synonymous with response in cyber became the trigger prefix for anything having to do with computers. Wiener took the governance and both metaphor a huge step forward control has to do with communications. He said the control connection is achieved, thanks to an invisible something called information control may require less or more information Wiener and Claude Shannon from Bethlehem's found a way to measure or quantify information exactly the formula adopted varies but stated in the most simple manner it's the unit of information called a bit an abbreviation for binary unit, currently known as a 0 or a 1. A bit conveys a unit of information where the probability of a message is .5 if more information is needed then more bits are needed to dispel the uncertainty.

The core concept behind the Macy foundation meetings was information feedback. A submarine torpedo racing towards the Steel Hulk of a ship guided by magnetic forces would be a good example of “error controlled purposeful behavior” smart bombs do the same they zero into a laser-painted target on the ground, so now in addition to having a cause-effect logic, a new logic was discovered a circular logic where a system is always changing its behavior according to the circular nature of the environmental impacts it has on its performance.

A thermostat automatically adjusting the behavior of a furnace to meet a certain room temperature is the classical example of this process. Feedback was the concept that connected the world of the living to the world of the mechanical cybernetics is the science that built a bridge between living things and physical processes. So not only that cybernetics linked worlds that were considered far apart, cybernetics also provided very powerful conceptual tools and the underpinnings of several of the sciences.

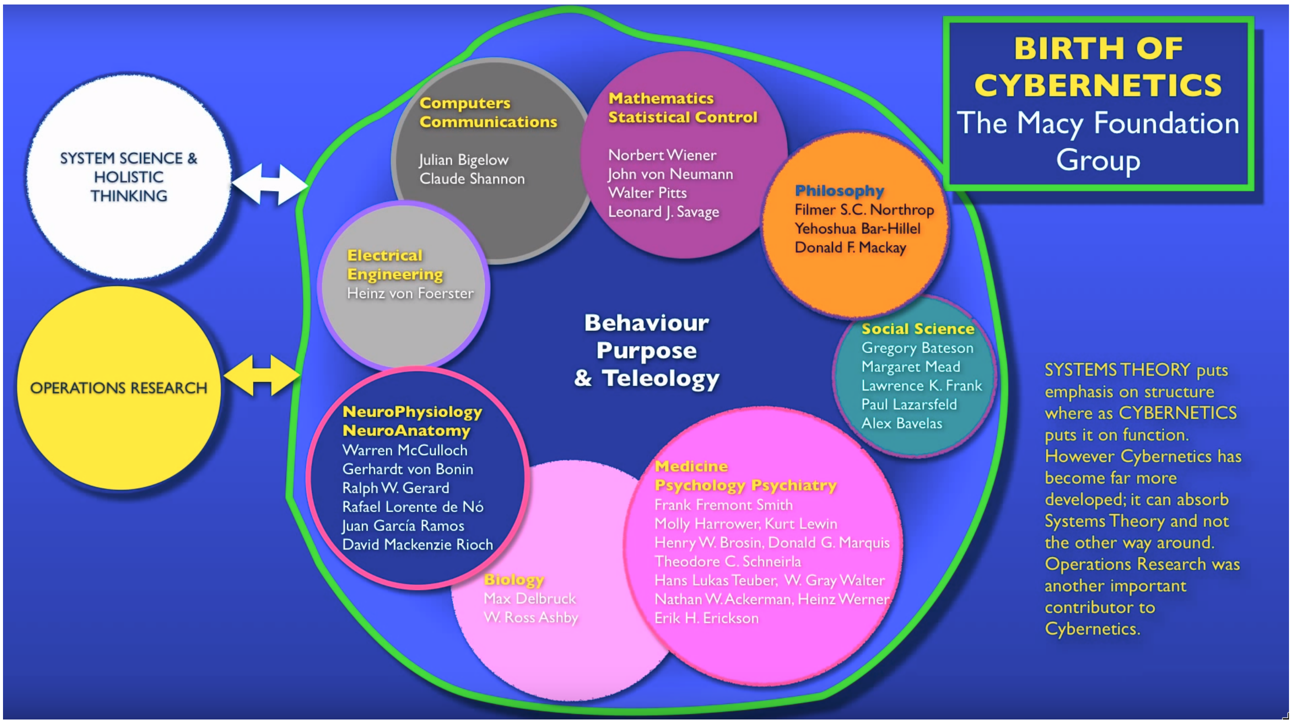
In this sense, our initial boat metaphor is replaced by a cargo ship carrying such tools; biology, psychology, sociology, engineering, and computer science. All of them contributed to the creation of cybernetics but also benefited from the new field of knowledge. The christening of the new science is a very touching story picture this, we are at the 1949 Macy conference the sixth one a sizeable group of beautiful minds give Wiener a big applause as they welcome cybernetics which was a title for a Rainer's new book to become the title for the conference's already in progress so cybernetics was adopted instead of “circular Castle in feedback mechanisms in biological and social systems” which was kept as a subtitle humbled by the gesture Wiener eyes show tears and he leaves the room to hide his emotions he seems immediately aware of his claim to immortality.

A total of ten Macy Foundation meetings on cybernetics were held from 1946 to 1953 all except one in New York City.

In total seventy well-known scientists participated this is the photograph taken of the attendance to the last meeting in 1953. In a parallel and compatible effort, systems-thinking and system science were being created by another group of holistic thinkers led by Ludwig Von Bertalanffy, Russell Ackoff, C. West Churchman and many many others.

Cybernetic topics were also boarded by the ratio Club in Great Britain which included Alan Turing, Ross Ashby, Gray Walter and others. Here is the map of the birth of cybernetics with some of the scientists related to each of the disciplines that made a contribution as we shall see the cybernetic paradigm will later engulf both cybernetics and system science.

W. Ross Ashby wrote “introduction to cybernetics” in 1956 as an introduction to Venus book, however it is a gigantic effort because it rebuilds cybernetics from scratch as a formal science in the same vein as logic or mathematics, he set down some of the basic concepts of the new science insists that its truths are not conditional under being derived from some other branch of science, as reinvents, idealize machines which are the equivalent of what ideal shape are to Euclidean geometry.



BIRTH OF CYBERNETICS
The Macy Foundation Group

SYSTEM SCIENCE & HOLISTIC THINKING

OPERATIONS RESEARCH

Computers Communications
Julian Bigelow
Claude Shannon

Mathematics Statistical Control
Norbert Wiener
John von Neumann
Walter Pitts
Leonard J. Savage

Philosophy
Filmer S.C. Northrop
Yehoshua Bar-Hillel
Donald F. Mackay

Electrical Engineering
Heinz von Foerster

Behaviour Purpose & Teleology

Social Science
Gregory Bateson
Margaret Mead
Lawrence K. Frank
Paul Lazarsfeld
Alex Bavelas

NeuroPhysiology NeuroAnatomy
Warren McCulloch
Gerhardt von Bonin
Ralph W. Gerard
Rafael Lorente de Nó
Juan García Ramos
David Mackenzie Rioch

Biology
Max Delbruck
W. Ross Ashby

Medicine Psychology Psychiatry
Frank Fremont Smith
Molly Harrower, Kurt Lewin
Henry W. Brosin, Donald G. Marquis
Theodore C. Schneirla
Hans Lukas Teuber, W. Gray Walter
Nathan W. Ackerman, Heinz Werner
Erik H. Erickson

SYSTEMS THEORY puts emphasis on structure where as CYBERNETICS puts it on function. However Cybernetics has become far more developed; it can absorb Systems Theory and not the other way around. Operations Research was another important contributor to Cybernetics.

cybernetics asks “what are all the possible behaviors this machine can produce” in this way, information theory comes to play an essential part of the subject because it is characterized essentially by its stealing always with a set of possibilities. Cybernetics deals with all forms of behavior insofar as they irregular determinate or reproducible, cybernetics offers the hope of providing effective methods for the study and control of systems that are intrinsically extremely complex.

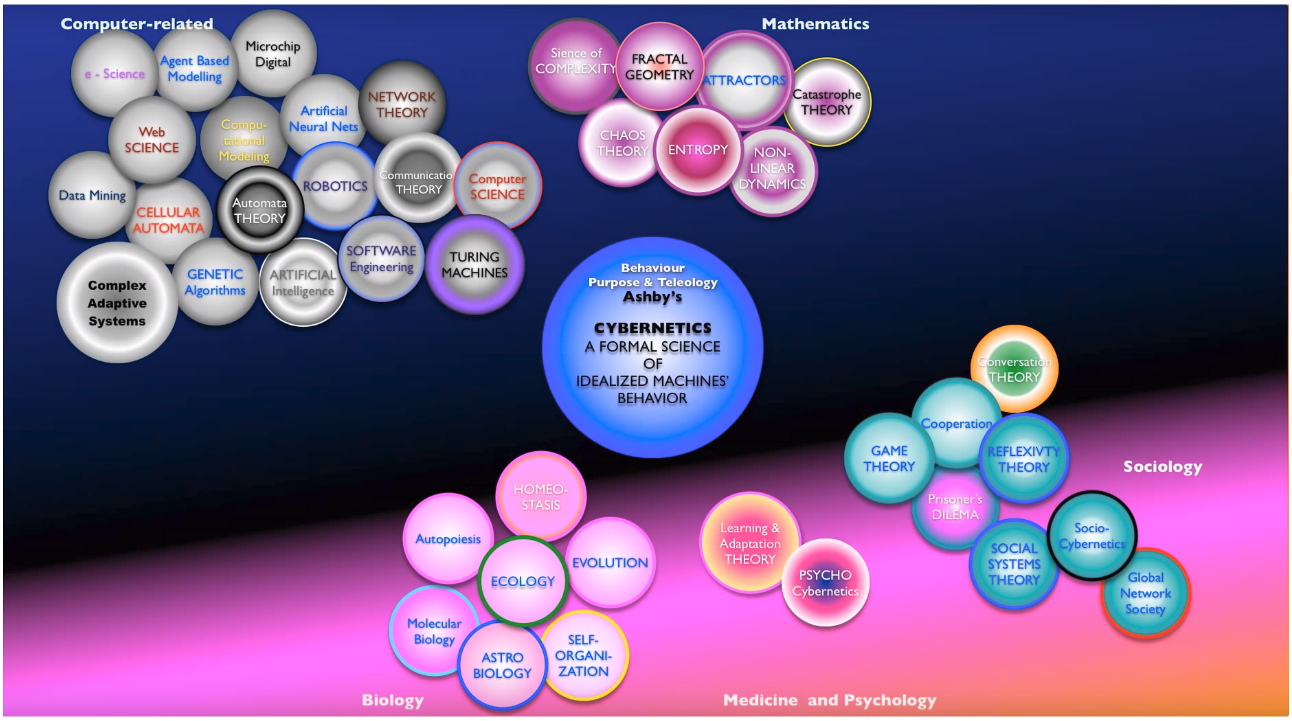
“It is chiefly one system become complex that the new methods reveal the power”, says Ashley, Ashby also introduces “difference” as a key cybernetic concept along with complexity and its scientific name “variety” as the crux of control theory.

Introduction to cybernetics demonstrates the law of requisite variety now known as Ashby’s law. This law of control reasserts itself in real life controlled situations in the same way that the law of gravity thus in the physical world. Here's an example of an idealized machine, a pencil, and paper machine much like a lantern Universal machine which is also a theoretical computer.

Ashby makes cybernetics a formal science about change using as I said difference as a key concept the concepts needed to regular it is the build the new cybernetics. The work of absolute genius it is Ashley's idealized machines cybernetics that provides the contributing Sciences with a common foundation, this is the reason for being able to say that many pre-existing theories and sciences become interconnected to Ashley's new cybernetics such as:

- Computers communications.
- Mathematics and statistical control.
- Philosophy.
- Social science.
- Medicine, psychology, and psychiatry.
- Biology.
- Neuro-physiology and neuro-anatomy.
- Electrical engineering.

The generality of advocacy and laws of control is outstanding Ashby's cybernetics houses all of these sciences very comfortably.



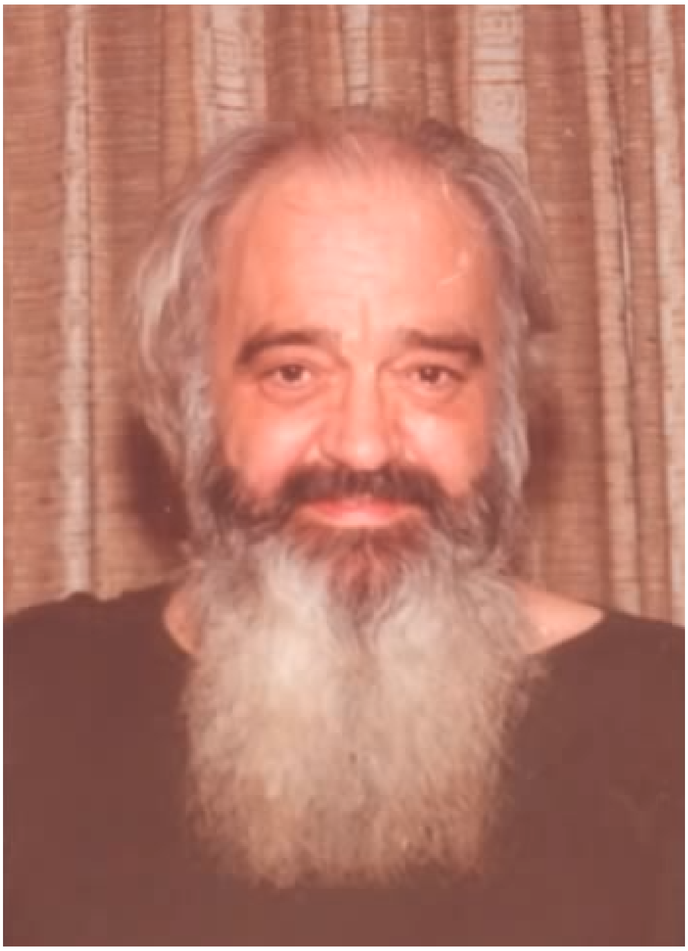
Here is a cluster of computer-related fields of knowledge some of them from the 40s and others quite recent. The Turing machine started it all Turing was the first to conceive the notion of a program running a computer this cluster groups; Turing machines, computer science, software engineering, communications theory, robotics, artificial intelligence, network theory, artificial neural nets, automation theory, genetic algorithms, cellular automation, complex adaptive systems, computational modeling, microchip digital technology, design agent-based modeling, web science, data mining, and assigns among others cybernetics is shown here in its connection to its related mathematics cluster through; attractors fractal geometry, entropy, chaos theory, non-linear dynamics, catastrophe theory, and the science of complexity all these are now cybernetics tools that help explain how life works a central objective of cybernetics. This mathematics become tools of a science that needs them to explain life and purpose.

The biology related cluster which starts with obvious thesis and adds; evolution, ecology, Auto police's, self-organization, molecular biology, and astrobiology there could be others in the Sociology cluster in which we find; conversation theory, game theory, cooperation, the prisoner's dilemma, reflexivity theory, social cybernetics, social systems, theory, and global network theory.

The psychology cluster is very large it includes adaptation theory learning theory, psycho-cybernetics, and many other related fields you as we just saw cybernetics was born as an interdisciplinary science a science of interrelatedness or interconnectedness but cybernetics have taken cybernetics to another level a new layer was added to it called second-order cybernetics it is the cybernetics of cybernetics.

Second-order cybernetics is about observing the observer of science it is a different way of looking at the world and everything in it a different way of making science by far more abstract so much so that it envelops both first-order cybernetics and also the methods of classical science the creation of second-order cybernetics turns cybernetics into a completely different scientific paradigm in its own right a different toolbox for building models of complex systems, interpreting data, and acquiring knowledge.

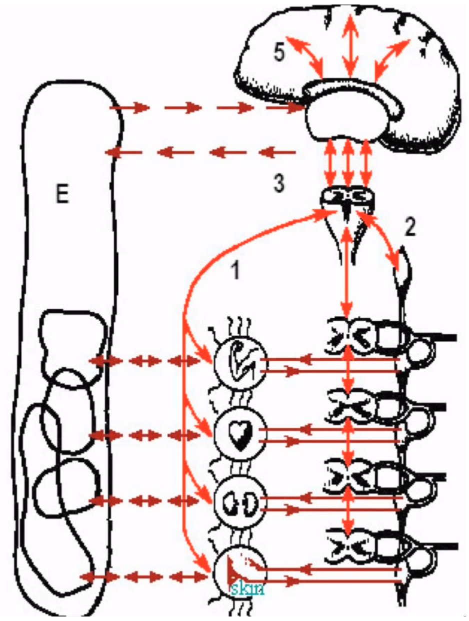
Second-order cybernetics was created by a group of thinkers and researchers led by Hinesville Forster and Gordon Pasque who see themselves as the offspring of the Macy group. They have more interest in concepts than in hardware the observer and the observed are treated as part of the same system, consequently, the non-linearities and paradoxes of self-reference have to be taken with a far higher greatness of understanding. This group initial concern was the theory of self-organizing systems thus the philosophy cluster includes, paradox, self-reference, emerges, the biology of cognition, constructivism, and experimental epistemology, in support of the ideas on self-organization you having included second-order cybernetics in our map.



It is now time to expand into management **cybernetics management**.

Cybernetics is linked to neuroscience and to all the cybernetic fields previously included. To create management cybernetics. Stafford Beer incorporates ideas from Wiener, Ashby, Von Forster, Pask, and others.

Let's call this the self-governance and collective governance area of cybernetics it starts with neuroscience management cybernetics feeds on neuroscience and as we saw to configure the viable system model it also feeds from second-order cybernetics, the VSM uses the idea of two observers, each with his own language level as indispensable in order to map complex organizations by talking in terms of a language and meta-language, the VSM can intrude successfully into highly complex fields of economics, law, and politics. I call this systemic organization the cybernetic state where cybernetic methods of collective intelligence will begin to play a major role in the future.



Stafford beer offers a definition of cybernetics as:

“The science of effective organization”

In the following graph we can see how neuroscience in Ashby’s law of representing Variety are incorporated into the viable system model.

Here is a map of the human nervous system on which the **VSM** is based on the Ashby law connection in present as a very large red spot indicating a sebacean homeostatic connection of different parts of an organization to its environment or even among its part.

The lower half of the organization speaks a certain **language**. The upper half of the organization speaks a **meta-language**, this is a key feature of the VSM that allows it to overcome the complexity barrier much in the same way as the brain filters out irrelevant information.

What is information

Eight superstar cyberneticians answer the question:

A very simple story about an answered phone call will help a lot to understand what information is all about. In the previous era someone was at a friend's home and the phone rang twice and stopped, then the friend said; “that means my dad's flight to New York and arrived safely” this way, we don't have to pay for the long business call we'll talk tonight when the rates are much lower. Information is anything that reduces uncertainty it is important to notice that it involves a hidden agreement. Like a contract, every word we say carries an implicit contract about its reading, the same is true for every letter of the alphabet.

After World War two, the cyberneticians got together to figure out how to communicate more efficiently or improve secret codes by using zeros and ones. They took advantage of the processing power of computers and change the world forever, today a phone call is worth peanuts and long business charges are gone.

However information is a tricky subject, these two videos[18] have erroneous statements when they talk about the amount of information and yet one of them has more than a million views.

Allow this document to present eight superstar sovereign additions to answer the question of what is information. Five of them participated in the creation of the Big Bang of the Information Age, this was during the Macy foundation meetings that took place in New York City from 1946 to 1953.

First Norbert Wiener, the father of cybernetics had it very clear, he said; information is information, not matter nor energy, the universe is made of energy, matter, and information, he also said information is also a measure of the organization of a system.

Following leader this shows how information energy and matter are intertwined, this gentle giant that went by the name of Gregory Bateson puts it bluntly, information is the difference that makes a difference. Following Bateson, information is not a material or physical thing nevertheless we need matter or energy or both to generate a difference that can be used to build a message.

We can use any objects; symbols, letters, pictures, memes, light or even a song or a movie to produce or convey information. Stafford Beer was not at the Macy conferences but he later became the father of management cybernetics, his definition of information says “information is what changes us” it is literally that which informs us, which gives us form.

Following Stafford Beer, when we say that every atom of the universe is “informed” about what it takes to BE an act like an atom we are talking about information as a primary concept, with the same scientific status as matter and energy. If we say we got information about a football game’s outcome, then we are using information as communication, in a more practical way.

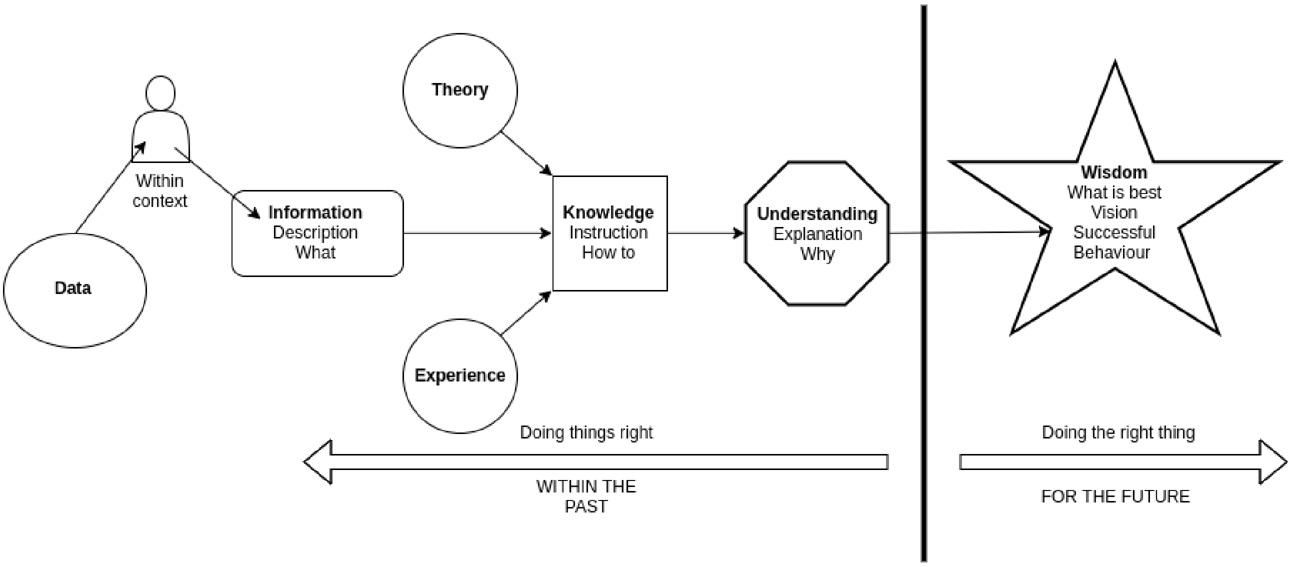
Russel Ackoff (1919 – 2009) was a great system thinker, he put all sorts of information into a neat little package, he says:

> “Data plus context equals information. Information plus rules equals knowledge”.

Russel Ackoff has broken information in its general sense to include data, specific information, knowledge, understanding, and wisdom.

---

[18] “How Much Information” from “Veritasium” & “What is information Theory? (Information Entopy)” from “Art of the Problem”



Claude Shannon who is considered the father of information theory did not consider the importance of meaning, therefore his definition of information was a purely quantitative measure of communication exchanges.

Ross Ashby gets into the thick of things and refutes Shannon, he says the transformation and storage of information is thus essentially related to the existence of a set of possibilities, the information carried by a particular message depends on the set it comes from, the information conveyed is not an intrinsic property of the individual message.

His wonderful book “an introduction to cybernetics” really explains all this and it is given for free by his family. Foster was against Shannon's subtraction of meaning he said:

> “Information even in the technical sense could not be severed from meaning without horrendous consequences for human understanding.”

His theory (meaning Shannon's) was really “signal theory” because information was not yet there. The moment one transforms that set of signals into other signals our brains can make an understanding of, then information is born!

It's not the beeps, Humberto Maturana, the Chilean biologist says: “everything said is said by someone”, meaning as a forester would say “an observer”.

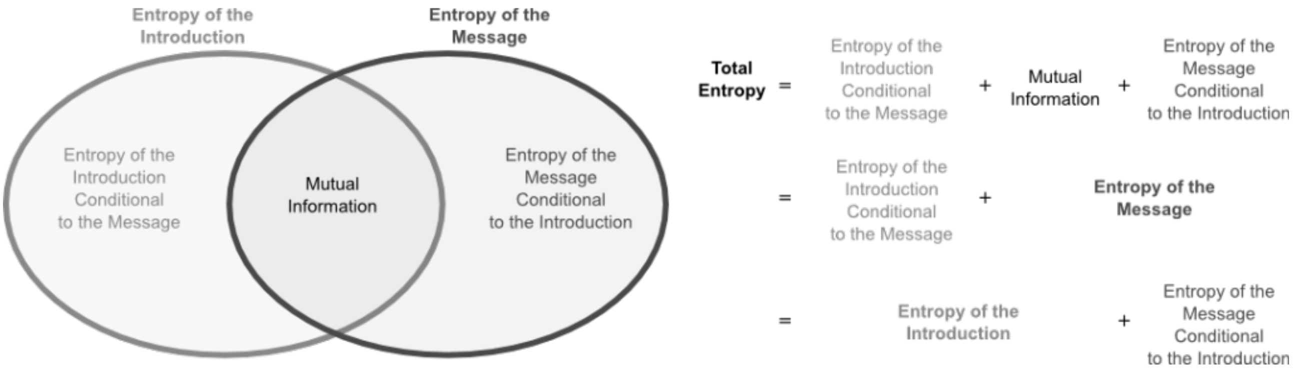
The point is you need an observer to point out a difference to notice the existence of information it makes little sense to talk about information being transmitted when there is no one to receive it, there is no such thing as information in a void, in the communication world, information is a relative concept. It press opposes the existence of an observer, it must be said that Ron Forster Maturana and beer collaborated in the creation of second-order cybernetics that is the cybernetics of cybernetics or the science of the observer. By doing so they elevated cybernetics into a new scientific paradigm, it's another way of doing science in contrast with the ultra-reductionist paradigm of Newtonian cause-effect science.

Today most science is based on the creation of models and is actually computerized science based on what I call a cybernetic approach of testing and adjusting models which on humans can be referred as the approach of providing experience and developing common sense.

Wiener and Shannon had a fundamental disagreement while Shannon said that information was entropy Wiener said that it was negentropy, history also has them clashing over who said what first Shannon published in the first part of his mathematical theory of communication. In july 1948 in it he introduced the notion of the binary digit creating the word bit, he also talks about channel capacity and redundancy among other things.

> “Information is a statistical substance as applied to messages.”
> - Weiner's way of thinking
>
> “I don’t care for meaning. I just want the bits and bytes I send to get trough.”
> - Shannon’s way of thinking

Shannon went further and quantified this sentence: “The entropy of a message is the sum of the entropy of its introduction and the entropy of the message conditional to its introduction!”


Entropy of the Introduction
Entropy of the Message
Entropy of the Introduction Conditional to the Message
Mutual Information
Entropy of the Message Conditional to the Introduction
Total Entropy = Entropy of the Introduction Conditional to the Message + Mutual Information + Entropy of the Message Conditional to the Introduction
= Entropy of the Introduction Conditional to the Message + Entropy of the Message
= Entropy of the Introduction + Entropy of the Message Conditional to the Introduction

$$H = -\sum_{i=1}^{n} p_i \cdot \log_2(p_i)$$

Shown at left is the formula both separate editions used to describe how to calculate the amount of information in a message one used to minus sign and the other did not. Wiener says “information is a statistical substance as applied to messages” and then I make up this other phrase by Shannon where he is rebuttal saying “I don't care for meaning I just want the bits and bytes I send to get through” it's a little joke.

What convinced Wiener to think of information as negentropy was Erwin Schrödinger's idea that life balance the second law of thermodynamics constantly in order to preserve the structure that keeps it going, information commands the energy the body ingests to rebuild itself so if thermodynamic entropy is the villain, then negentropy is the hero life is sustained by information processes or you guessed negentropy, information and entropy are rivals one in favor of life the other constantly trying to stop it.

Wiener solution makes much more sense than chance, it is better thought.

Shannon gave Wiener credit for some of the central ideas of his new mathematical theory of communication, however history has given the credit of information theory to Shannon now it will read this timeline we see that it does just as the Wiener, Shannon is seen as the father information or information theory, but the truth is he was more into communications, "effective information transmission", but in his passion for accurate transmission disregarded meaning.

Please notice: a 0 or a 1 do not carry the same information if the probability of the event to which they are attached is not the same. Wiener's unit amount of information refers to two equally probably alternatives, as in a flip of a coin, but not necessarily in every "Yes or No" question.

If you ask did it rain when chances were low, a "yes" carries much more information than the "yes" of a 50-50 chance of rain. This is the reason why the two videos have wrong statements.

Information theory

Information theory studies the quantification, storage, and communication of information. It was originally proposed by Claude E. Shannon in 1948 to find fundamental limits on signal processing and communication operations such as data compression, in a landmark paper entitled "A Mathematical Theory of Communication".

Applications of fundamental topics of information theory include lossless data compression (e.g. ZIP files), lossy data compression (e.g. MP3s and JPEGs), and channel coding (e.g. for digital subscriber line (DSL)). Its impact has been crucial to the success of the Voyager missions to deep space, the invention of the compact disc, the feasibility of mobile phones, the development of the Internet, the study of linguistics and of human perception, the understanding of black holes, and numerous other fields.

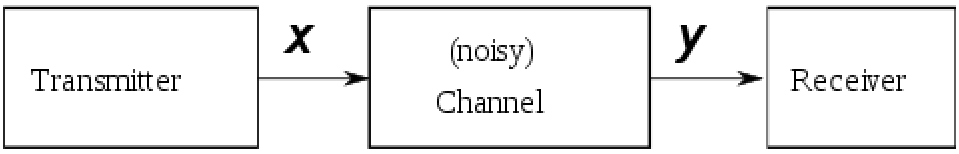
> "Information theory studies the transmission, processing, extraction, and utilization of information."

A key measure in information theory is "entropy".

Entropy quantifies the amount of uncertainty involved in the value of a random variable or the outcome of a random process. For example, identifying the outcome of a fair coin flip (with two equally likely outcomes) provides less information (lower entropy) than specifying the outcome from a roll of a die. The difference is the the roll of the dice provide six equally likely outcomes.

Some other important measures in information theory are:

- **Mutual information:** Mutual information measures the amount of information that can be obtained about one random variable by observing another. It is important in communication where it can be used to maximize the amount of information shared between sent and received signals.
- **Channel capacity:** Communications over a channel often fail to produce exact reconstruction of a signal; noise, periods of silence, and other forms of signal corruption often degrade quality. Consider the communications process over a discrete channel. A simple model of the process is shown below:



Here X represents the space of messages transmitted, and Y the space of messages received during a unit time over our channel. Let p(y|x) be the conditional probability distribution function of Y given X. We will consider p(y|x) to be an inherent fixed property of our communications channel (representing the nature of the noise of our channel). Then the joint distribution of X and Y is completely determined by our channel and by our choice of f(x), the marginal distribution of messages we choose to send over the channel.

Under these constraints, we would like to maximize the rate of information, or the signal, we can communicate over the channel.

The appropriate measure for this is the mutual information, and this maximum mutual information is called the channel capacity and is given by:

$$C = \max_{f} I(X;Y).$$

This capacity has the following property related to communicating at information rate R (where R is usually bits per symbol). For any information rate R < C and coding error ε > 0, for large enough N, there exists a code of length N and rate ≥ R and a decoding algorithm, such that the maximal probability of block error is ≤ ε; that is, it is always possible to transmit with arbitrarily small block error. In addition, for any rate R > C, it is impossible to transmit with arbitrarily small block error.

Channel coding is concerned with finding such nearly optimal codes that can be used to transmit data over a noisy channel with a small coding error at a rate near the channel capacity.

  - **Binary symmetric channel:** In this model, a transmitter wishes to send a bit (a zero or a one), and the receiver receives a bit. It is assumed that the bit is usually transmitted correctly, but that it will be "flipped" with a small probability (the "crossover probability"). This channel is used frequently in information theory because it is one of the simplest channels to analyze.

    Many problems in communication theory can be reduced to a BSC. Conversely, being able to transmit effectively over the BSC can give rise to solutions for more complicated channels.

  - **Binary erasure channel:** A binary erasure channel (or BEC) is a common communications channel model used in coding theory and information theory. In this model, a transmitter sends a bit (a zero or a one), and the receiver either receives the bit or it receives a message that the bit was not received ("erased"). This channel is used frequently in information theory because it is one of the simplest channels to analyze. The BEC is, in a sense, error-free. Unlike the binary symmetric channel, when the receiver gets a bit, it is 100% certain that the bit is correct. The only confusion arises when the bit is erased.

    This channel is often used by theorists because it is one of the simplest noisy channels to analyze. Many problems in communication theory can be reduced to a BEC.

- **Error exponents:** In information theory, the error exponent of a channel code or source code over the block length of the code is the logarithm of the error probability. For example, if the probability of error of a decoder drops as e−nα, where n is the block length, the error exponent is α. Many of the information-theoretic theorems are of asymptotic nature, for example, the channel coding theorem states that for any rate less than the channel capacity, the probability of the error of the channel code can be made to go to zero as the block length goes to infinity. In practical situations, there are limitations to the delay of the communication and the block length must be finite. Therefore, it is important to study how the probability of error drops as the block length go to infinity.

- **Relative entropy:** In mathematical statistics, the Kullback–Leibler divergence (also called relative entropy) is a measure of how one probability distribution diverges from a second, expected probability distribution. Applications include characterizing the relative (Shannon) entropy in information systems, randomness in continuous time-series, and information gain when comparing statistical models of inference. In contrast to variation of information, it is a distribution-wise asymmetric measure and thus does not qualify as a statistical metric of spread. In the simple case, a Kullback–Leibler divergence of 0 indicates that we can expect similar, if not the same, behavior of two different distributions, while a Kullback–Leibler divergence of 1 indicates that the two distributions behave in such a different manner that the expectation given the first distribution approaches zero.

Amplifiers: Let it face the actual problem of communication. The unpredictable perturbation of the message! This perturbation is called noise. This noise is precisely what prevents a message from getting through. When you're amplifying the message, you're also amplifying the noise. Thus, even though the noise is small, as you amplify the message over and over, the noise eventually gets bigger than the message. And if the noise is bigger than the message, then the message cannot be read. Now, instead of simply amplifying the message, we can read it before. Because the digitized message is a sequel of 0s and 1s, it can be read and repeated exactly. By replacing simple amplifiers by readers and amplifiers (known as regenerative repeaters), we can now easily get messages easily. It therefore performs pulse regeneration to restore the original shape of a pulse signal used in teletypewriter and other code circuits.

About systemic governance

> “A viable system is any system organized in such a way as to meet the demands of surviving in a changing environment.”

Systems are complex to govern, difficult to maximize its potential, extremely difficult to adapt (do the rights things) in terms of innovation and transformation. Most innovation and transformation initiative fail, large percentage of listed companies over a 30 year period have disappeared. Organizations such as Kodak, Motorola and Nokia from being market leaders have basically disappeared. These organizations are not strangers to innovation yet their innovation or lack of transformation triggered their downfall. Economic system either fail to grow adequately or are in permanent decline or they leverage the economic via toxic and dubious financial mechanism.

This applies to all system: **The performance of the system** depends on how well the parts fit together, **not how well they perform individually** and the “whole” system exhibits emergent properties that are not to be found in its parts.

The performance of the system is not the sum of the performance of its parts but rather determined by the efficacy of its parts and specifically the efficacy of the parts relationship to realize system purpose.

The ‘whole’ of the German economic system are quite different so Italy ‘whole’ system. This applies to a football team, automobile company etc...

In certain cases adaptation effort that generates more system damage or triggers serious side effects impacting system performance; typical example Italy fiscal compact constraints not only reduced output, it increased unemployment and public debt. Why is that? Reality governors fail to effectively govern the system, fail to act upon emergence (consequences) that have serious negative impact on the system.

Purpose of this blog is to provide overview of systems, problems related to effective system governance, how to govern the system to achieve maximum potential and remain viable and provide pathway for effective adaptation (doing the right things).

A viable system is any system organized in such a way as to meet the demands of surviving in a changing environment.

> **“A system is a set of elements or parts that is coherently organized and inter-connected in a pattern or structure that produces a characteristic set of behaviors, often classified as its function or purpose.”** (Donella Meadows)

The performance of the system depends on how well the parts fit together, not how well they perform individually. Thus, the best parts do not necessarily make the best whole; **they have to fit together**. The 'whole' system exhibits emergent properties that are not to be found in its parts (sub-systems). System effectiveness and efficiency which in turn influence system performance are attained through the interaction of the sub-systems in pursuit of the purpose of the system in its environment.

A system consists of a interconnected set of elements (sub-systems) that are coherently organized and work in coordination with each other to achieve a desired goal or overall objectives of the whole (purpose) as defined by its governors (managers, leaders) via defined '**set course**'. These elements derive their strength by means of association and influence with other elements whereby collective contribution of the system is greater aggregate individual elements: **this is known as systemic synergy**. Systems contain the following elements which form a **complex and unified whole:**

- Elements (system)
- Interconnection between elements (system's data flow)
- Attributes to both system elements and relationships (system's properties)
- System purpose and sub-systems functions (system's systems)

Systems are everywhere — for example: the R&D department, the human body, F1 racing team, automotive manufacturer, economic and political systems.

Languages are systems of communications protocols designing a structure — It lays upon a few basic approaches for most common communications protocol. Words are defining the nature of a system or system's classes in other words. Adjectives are defining properties of systems within their respective classes meanwhile verbs are defining system's actions or system's interactions depending on the point of view defined by the subject within the context.

> "Can you talk about a language using the very same language to construct a new language? This is the foundation of the second and third order cybernetics."

Ecological systems and human social systems are **living systems** oriented towards system **purpose**; human-made systems such as manufacturing plant or Information technology architecture are **nonliving systems** which are oriented towards system **function**.

Systems can also be made up of sub-systems that that can either have function or purpose.

> “A sustainable system is any system organized in such a way as to meet the demands of a changing environment and achieve is stated goal in time.”

Resilience is the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks. Adaptability is the capacity of actors in a system to influence resilience.

Resilience is not simply just about doing the right things; but rather the right things to do (of what to what) considering internal and external conditions; system trajectory and stability landscape. Doing the right things does not imply success; they **might even trigger side effects** that create further damage of reduce system performance.

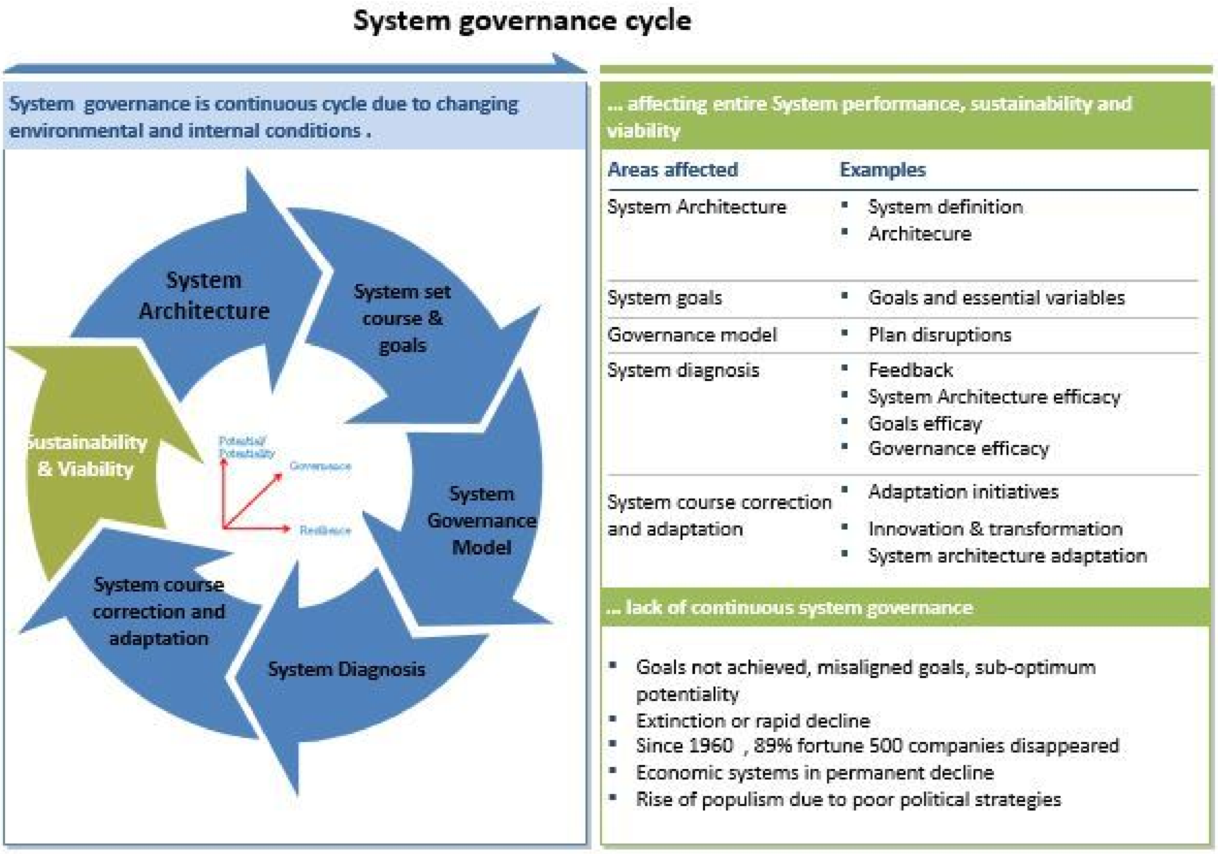
Adaptability is the capacity of system to influence resilience, restore potential and mange disturbances considering diversity, system leadership, regimes, dynamics balance and scales.

While transformability is the capacity to create a fundamentally new system when ecological, technological, economic, or social (including political) conditions make the existing system untenable (**Paradigm Shift**).

A system needs to be continuously **governed**; **steered**, **adapted and transformed** in order to be sustainable, survive (viable), grow and achieve its goals. It is fundamental when undertaking systemic transformation to **avoid costly mistakes** that can be detrimental to viability and sustainability.

System failure does not stem from cause and effect relationship but from pathology of the system as a whole. If the individual or their organization is incapable of associating effects with their causes, then learning and adaptation is not possible and both will go on repeating the same error. System governance is a continuous cycle due to systemic external and internal conditions requiring effective adaptation.

According to Doerner (cf Doerner 1992) **six classes mistake** people are prone to make in coping with and intervening in complex systems:



System governance cycle

System governance is continuous cycle due to changing environmental and internal conditions .

... affecting entire System performance, sustainability and viability

Areas affected	Examples
System Architecture	▪ System definition ▪ Architecure
System goals	▪ Goals and essential variables
Governance model	▪ Plan disruptions
System diagnosis	▪ Feedback ▪ System Architecture efficacy ▪ Goals efficay ▪ Governance efficacy
System course correction and adaptation	▪ Adaptation initiatives ▪ Innovation & transformation ▪ System architecture adaptation

... lack of continuous system governance

- Goals not achieved, misaligned goals, sub-optimum potentiality
- Extinction or rapid decline
- Since 1960 , 89% fortune 500 companies disappeared
- Economic systems in permanent decline
- Rise of populism due to poor political strategies

- [Class I] The perception and description of system objective is too narrow. It is imperative to **clearly define the system** in order to understand the system and its emerging behaviour.
- [Class II] The situation analysis of a system focuses on quantitative data and static aspects without considering dynamics and causal relationship. Systemic transformation requires thorough **system architecture** and dynamic **analysis**.
- [Class III] Intervention in a complex system irreversibly focuses on single favorite aspect. This can be overcome by means of relevant transparent teams to address problems and adaptation adopting **Team Synergy** to filter-out bias.
- [Class IV] Blindness of side effects. This can be overcome by adopting **Causal Loop** diagrams to identify cause and effect relationship and more important identify emerging patterns of behavior.
- [Class V] The intervention is a complex system are first to weak and then too strong. **System dynamics** modelling can be used to **evaluate efficacy of intervention**. Systemic cockpit is also fundamental to evaluate systemic state, achievements of its goals and via feedback its efficacy.

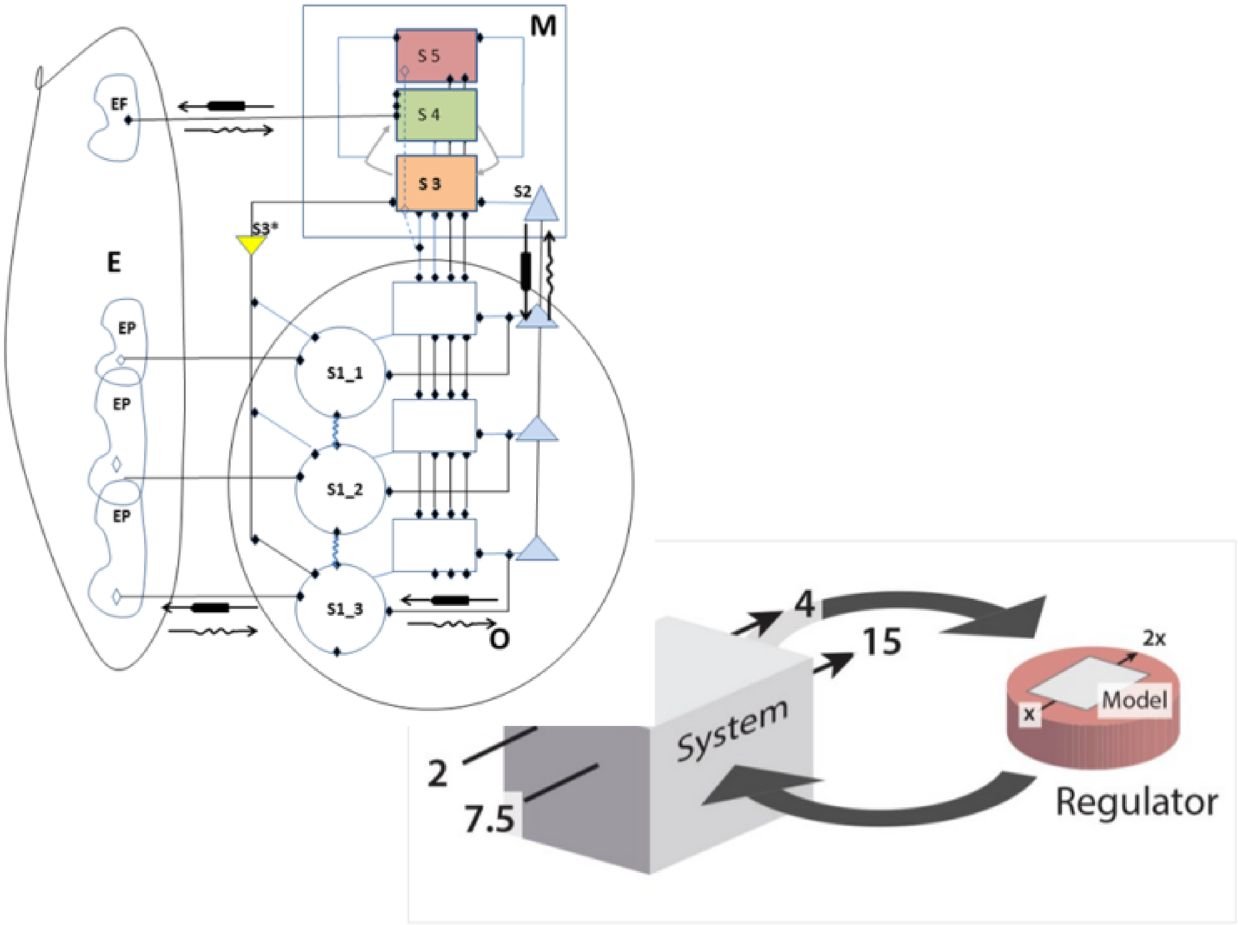
- Class VI : The intervention in complex system is dominated by authoritative behavior that overestimates level of understanding of the system. This can be overcome by means of adopting **Viable System Model** as a governance approach for design and diagnosis furthermore **Team Syntegrity** tend to diminish authoritative behavior.

System governance

About system governance

A system needs to be continuously governed; **steered**, **adapted and transformed** in order to be sustainable, survive (viable), resilient, **achieve maximum potential**, grow and achieve its goals. This is possible when there is:

1. **Clear understanding of the system** structure and behavior : purpose, function, elements, relationship, and properties.
2. **Adaptation** is only possible with **effective governance structure** in place that allows continuous adaptation and ensure system efficacy, effectiveness, sustainability, and viability.
3. **Effective steering** is only possible with a systemic **cockpit that indicates system** set course, goals, key variables, actual system state, governance efficacy diagnosis, initiatives to align to set course, models of the organization.
4. **Effective steering** can only be achieved with **correct feedback**: the correct action to correct the system current course: continuously addressing sustainability and efficacy.
5. **Effective steering** implies ability to **learn from previous steering** attempts to either avoid repeating damaging conditions or actually apply experience to amplify improvements.
6. **Effective steering** is only effective when the control tower contains essential variables **associated to goal state**.
7. **Effective steering** means being able to address effective form of adaptation and goals: **identifying opportunities for transformation** (new industry paradigm) and or innovation initiatives.



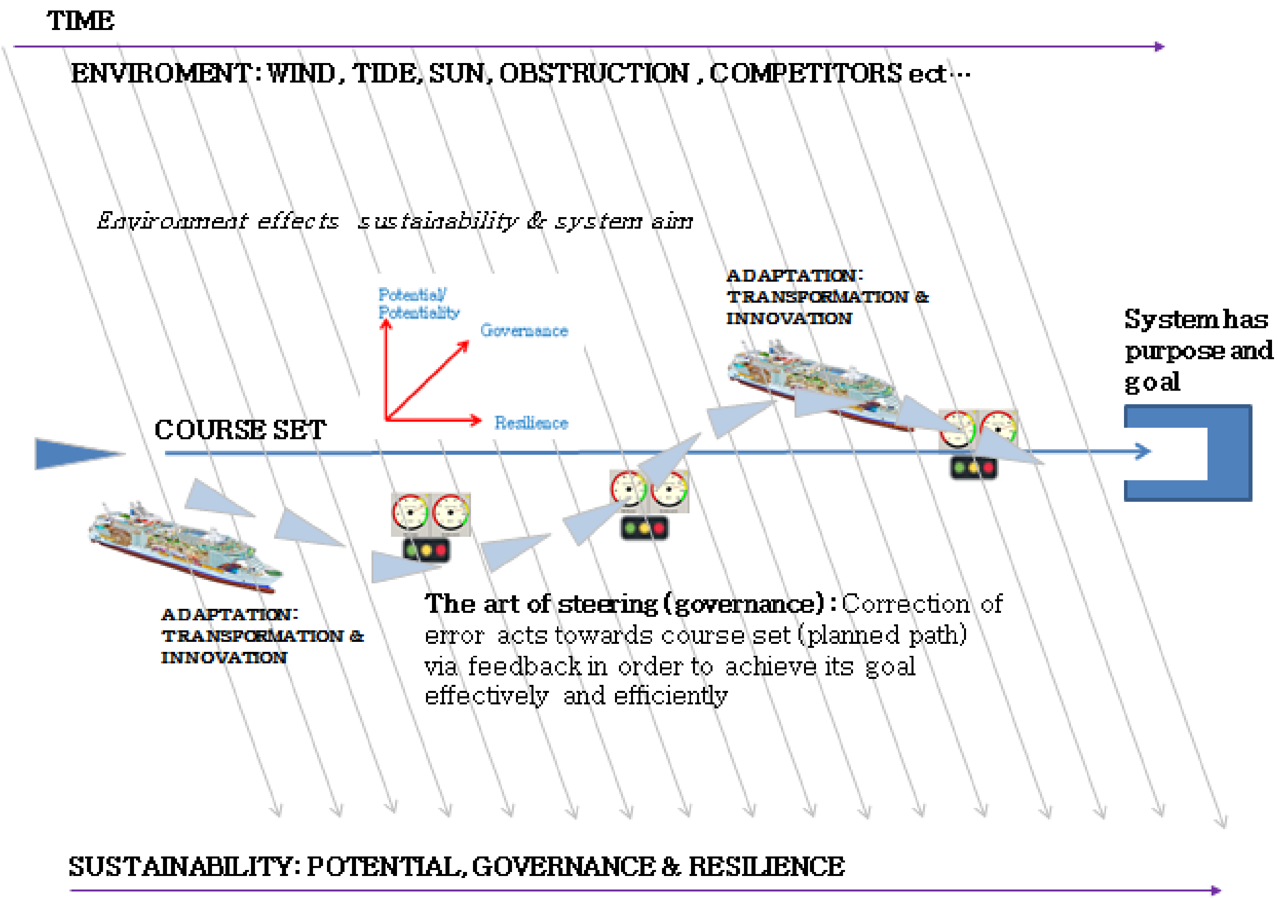
The Conant-Ashby Theorem, which states that “every good regulator of a system must be a model of that system”. Or in everyday language, to control a system you have to have a model of how it works.

> By Analyzing **“to control a system you have to have a model of how it works”**; what does this imply?

It implies always starting with a baseline of the system (System Architecture baseline 0) indicating as if functioning of the system, its performance, behavior and effectives. The baselines then forms foundation for effective steering towards stated goals, applying effective adaptation. Applying effective adaption implies doing the right things considering system state, environmental conditions and future projection. Doing the right things implies.

- Addressing system potential and potentiality.
- Reviewing validity purpose, mission, vision and goals.
- Effective innovation and transformation.

From this various models are applied with respect to adaption to a new baseline.


TIME
ENVIROMENT: WIND, TIDE, SUN, OBSTRUCTION , COMPETITORS ect…
Environment effects sustainability & system aim
Potential/ Potentiality
Governance
Resilience
ADAPTATION: TRANSFORMATION & INNOVATION
System has purpose and goal
COURSE SET
ADAPTATION: TRANSFORMATION & INNOVATION
The art of steering (governance) : Correction of error acts towards course set (planned path) via feedback in order to achieve its goal effectively and efficiently
SUSTAINABILITY: POTENTIAL, GOVERNANCE & RESILIENCE

Steering

- **The art of steering** is to ensure that System state is as close as possible to its set course by carrying out necessary effective correction (adaptation doing the right things):
- **Correction** to ensure set course goals are satisfied:
  Feedback to ensure system state course is adjusted to intended set course.
- **Ensuring achievement** of optimal system capability and potentiality:
  Constraint management.
- **Ensuring effective realization** of stated goals and continuous learning from system dynamic emergence (cause and effect). Being effective is about doing the right things, while being efficient is about doing the things right with respect to sustainability, maintaining the set course and achieving sated goals. This is only possible within a comprehensive adaptation framework: Multi dimension sustainability assessments and adaptation:

  - **Potential** sets the limits to what is possible – the number and kinds of future options available. Maximizing potential considering current and future environmental conditions by undertaking transformation and adaptation. This is done via extensive modeling and team effort (team syntegrity) which may lead to system transformation (system paradigm change) and or innovation effort.
  - **Governance** determines the degree to which a system can control its own destiny through internal controls. This implies designing an effective governance model for the system that will ensure viability and sustainability.
  - **Resilience** determines how vulnerable a system is to unexpected disturbances and surprises that can exceed or break that control. This implies understanding system resilience and threshold and trying to influence its threshold to favorable state.

Systemic adaptation is a continuous process of steering (course correction) and effective adaptation by ensuring that at any time system ideal potential, governance and resilience are maintained.

Staying on course

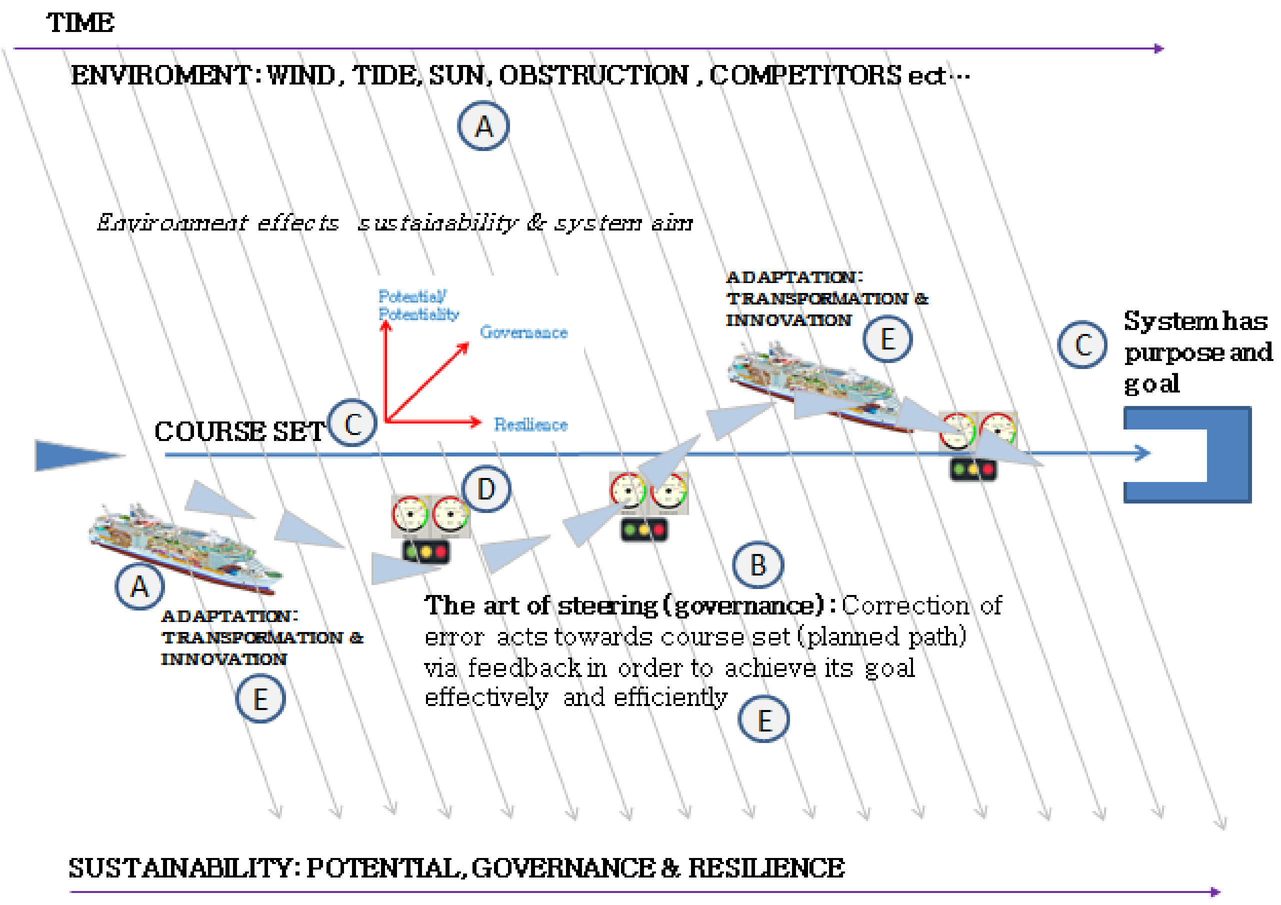
The fundamental aspect with respect to adaptation is to ensure that the rights things are done correctly when steering to avoid costly mistakes that can seriously undermine sustainability (viability, survival). There are ample examples of catastrophic failure considering disappearance of major organization such as Nokia, Texas Instruments, Polaroid, Palm: or catastrophic failures that required substantial government intervention such as banks or countries that are in permanent decline and survive thanks to excessive borrowing yet fail to grow and ensure a sustainable economy.

- Initiatives that do not consider side effects or purposely avoiding side effects for short term gains.
- Poor feedback management.
- Unable to effectively manage complexity and variety.
- The wrong intensity of the intervention which could be firstly too weak then to strong (high cost of intervention) resulting excessive oscillation or failure to emerge from systemic vortex.
- Intervention by authoritative behavior that underestimates understanding of system complexity: failure to exploit internal resources and teams. Focusing on CEO master of all

- Intervention focused on single favorable aspect instead of considering systemic intervention.
- Description and perception of system objectives too narrow.
- Excessive focus on quantitative static data rather than dynamic behavior.
- Excessive investment in sub-system that provide limited leverage: extensive IT investment.
- Avoiding transformation and placing excessive emphasis on innovation: or ineffective innovation.
- Failing to manage system resilience.

Steering framework

In order for a system to maintain its course efficiently and effectively the following framework needs to be in place which must be supported by means of System cockpit:


TIME
ENVIROMENT: WIND, TIDE, SUN, OBSTRUCTION , COMPETITORS ect…
A
Environment effects sustainability & system aim
Potential/ Potentiality
Governance
Resilience
ADAPTATION: TRANSFORMATION & INNOVATION
E
C
System has purpose and goal
COURSE SET
C
D
A
ADAPTATION: TRANSFORMATION & INNOVATION
E
B
The art of steering (governance): Correction of error acts towards course set (planned path) via feedback in order to achieve its goal effectively and efficiently
E
SUSTAINABILITY: POTENTIAL, GOVERNANCE & RESILIENCE

System Definition

In order to effectively govern the system (internal and external) and ensure effective organizational design and intervention; system definition plays an important role in placing the system into perspective.

A system must consist of the following:

- Function or purpose. **Function is used for a non-human systems, while purpose for a human one**. Many systems have both human and non-human elements. Purposes are deduced from behavior, not from rhetoric or stated goals.
- **Elements** : structure define by parts and compositions.
- **Behavior** which involves inputs, processing of outputs of materials, energy or information.
- **Static and dynamic properties** of both elements and relationship channels.
- **Variables associated to both elements and relationship.**
- **Interconnection**: parts have functional and structural relationship between each other; relationships hold the elements together whereby there may be physical flow and or information flow between elements. Many of the interconnections in systems operate through the flow of information. Information holds systems together and plays a great role in how they operate.
- **Systems** (strictly always sub-systems) within systems that may have either unique purpose of function.

System governance

Governance implies the ideal structure necessary to effectively control (steering, adaptation) the embedded. Governance not only implies effective design but also diagnosis of the governance structure in order to **ensure continuous synergy between** normative, strategic and operation management considering changes in environment system state versus the set course:

- **Normative management**: Defying policy, identity, ultimate authority decisions within the organization as a whole to balance demands from different parts of the organization and steer the organization as a whole. Normative management (system 5) develops the organization’s overall vision and strategy.

- **Strategic management**: responsible for looking outwards to the environmental scanning, strategy, planning and innovation and to monitor how the organization needs to adapt to remain viable.
- **Operation Management**: Management functions associated with systems 1, 2, 3 and 3* with respect to delivery of service and products towards its known environment.
- **Process Management**: Process management is a systematic approach to making an organization's workflow more effective, more efficient and more capable of adapting to an ever-changing environment. A business process is an activity or set of activities that will accomplish a specific organizational goal.
- **Ability to deal with complexity** between environment and operational units, dynamics, intermediates, operational units an management: In organizational cybernetics implies that two elements (environment and operation units or operation units and meta management) which strive for successful interaction and control either require an equal amount of variety or they need (meta-)attenuators and / or (meta-)amplifiers of their variety in order to attain mutual balance levels of variety in order to be successful in their interaction
- **Sub-system management**
  - Information Technology Architecture
  - Systemic IT Architecture addresses aligning IT systems, applications, information and data, network and infrastructure to support the systemic transformation systems to realize outputs within management defined goals
- **Equipment and facilities**
  - The system cockpit should provide a visual diagnosis with respect to the governance structure.

System goals and course set

This implies identifying and agreeing to system goals and plotting a set course in reaching these goals by identifying key essential variables against which effective steering. Fundamental variables to include variable related to system key goals, system potential and resilience. Variables need to be effectively associated to system elements and relationship in order to clearly associate emerging systemic behavior.

System cockpit plays and important role for effective steering and governance. The control of a systems can never be a matter of one-time decision-making, but rather it requires perpetual cycles of acts and affects which over time any effect becomes the reason for another. (cf. Foerester & Poerksen 2011, p 107).

Effective control tower ensures that the system is steered as close as possible to set course and it enables clear understanding of the effectiveness of its steering effort and adaptation initiatives.

The key purpose of the systemic cockpit is to be an enable effective governance of the system understudy:

- How the system (organization) works or does not work.
- Why it works in a specific way.
- The responsiveness and efficacy of its steering and adaptation initiatives.
- What to do (steering and adaptation) about the system (organization) to influence the outcome in a way which is beneficial to the purpose being served.

The art of steering

The art of steering or governance by ensuring effective correction of error towards defined course set in order to achieve stated goals with the aid of systemic cockpit. Steering has to ensure that there are management entities (VSM Framework) in place to co-ordinate the interfaces of its value-adding functions and the operations of its primary sub-units. In other words, co-ordination is necessary between the value-adding functions as well as between the embedded primary activities in order to optimize and achieve synergy, optimization and synchronization in order to maximize **potentiality and capability**.

Control channel from operational management through which resources are negotiated, direct line management instructions and goals are issued and accountability reports flow upwards to keep the meta-level management in touch with events.

Fundamental aspect steering and control is to ensure is total cohesion by all the sub-systems with respect pursuit of system purpose.

System correction and adaptation

If the individual or their organization is incapable of associating effects with their causes, then learning and adaptation is not possible and both will go on repeating the same error.

Actual correction by means of feedback within known system structure and process as well as adaptation initiatives which can either be related to Transformation and / or Innovation with the aid of Team Syntegrity initiatives. Key focus with respect to adaptation is to **identify initiatives** that enable cost effective leverage.

The Intelligence function management by the **strategic management service** is the two-way link between the primary activity and its external environment. Intelligence is fundamental to adaptability; provides the primary activity with continuous feedback on marketplace conditions, technology changes and all external factors that are likely to be relevant to it in the future; secondly, it projects the identity and message of the organization into its environment. The **intelligence function is strongly future focused**. It is concerned with planning the way ahead in the light of external environmental changes and internal organizational capabilities so that the organization can invent its own future (as opposed to being controlled by the environment), create new industry paradigm, elevate its potential, provide operations management **guidance with respect to adaptation.**

Complexity of system management, governance and adaptation

Generally systems are difficult to manage due their complexity and rapidity changing environment.

Adaptation, innovation and transformation are extremely difficult to manage and realize; 'doing the rights things'. This difficulty is mainly associated with failing to understand complexity and the variety propagated by systems and too much reliance on single managers or super CEO. Many fail to exploit the cognitive intelligence available to them to do the rights things.

Typical example of expecting too much from single person to execute major transformation relates to HP: http://www.forbes.com/sites/frederickallen/2012/03/05/why-great-innovations-fail-its-their-ecosystem/#a2e4aa6b5336. HP Carly Fiorina may be an excellent CEO but it does not imply the CEO has the ability to carry-out major transformation and successfully introduce industry paradigm. Same can be said about Steve Jobs: very successful with iPhone, tablets ect..; but it does not imply that Steve Jobs at Nokia would have made a difference.

Nokia (https://hbr.org/2011/02/the-real-cause-of-nokias-crisi.html) further example adaptation failure: in this case adaptation issue was not related to innovation but more related to fact that their whole governance model was based on a crumbling paradigm impacting their resilience. They failed to understand that innovation in a crumbling paradigm can only lead to failures.

Within the European Union specifically Euro member country there are countries with exceptional performance such as Germany while Italy exceptional low performance. Is this caused by the Euro or is it mainly due to poor system governance that limits potential and limited resilience.

Why innovation fails?

http://fortune.com/2014/10/07/innovation-failure/

> **"If you had to guess, what percentage of ideas for ground-breaking new products or services would you say are marketplace flops, or just never see the light of day? 50%? 80%? According to Mark Payne, it's closer to 90%"**

Why transformation fails?

The reported failure rate of large-scale change programs has hovered around 70 percent over many years.

http://www.mckinsey.com/business-functions/mckinsey-recovery-and-transformation-services/our-insights/transformation-with-a-capital-t?cid=soc-web

Accenture: According to Gartner, "almost 90% of transformation projects miss their mark."

According to research by McKinsey & Company, about 70% of all changes in all organizations fail.

After almost two decades of intense change from corporate reorganizations, new software systems such as ERP, and quality-improvement projects (six sigma) , the failure rate remains at 70%. Project failure not only has impact on cost but can actually result in major decline.

When changes fail, people often grow cynical impacting motivation and become afraid of their current and future security.

Thinking about the system

Systems Thinking is a way of thinking about life, work, and the world based on the importance of relationships (**interconnections**). Systems Thinking also provides a language and a scientific technology for understanding and dealing with complexity and change.

Systems Thinking has three aspects. These aspects can be used individually or in combination. They are:

1. A way of thinking (**paradigm**) about the world and relationships. The Systems Thinking Paradigm consists of a set of principles and theories.
2. A language for understanding change, uncertainty and **complexity**. The Systems Thinking language uses diagrams to explain non-linear cause and effect relationships.

3. A methodology for modeling complex situations underlying business, economic systems, scientific, and social systems. Systems Thinking modeling tools can be used to create powerful simulation models of organizational situations such as strategy development, process design and re-engineering, and team and organizational learning. Modelling create ability to create models that address specific problems, hell to maximize capability and potentiality, leverage potential, understand variety engineering.

What exactly is a system? A system is a group of interacting, interrelated, and interdependent components that form a complex and unified whole. Systems are everywhere — for example, the R&D department in your organization, the human body, F1 racing, the ecosystem, economic and political systems. Ecological systems and human social systems are living systems oriented towards **system purpose**; human-made systems such as cars and washing machines are nonliving systems which are oriented towards **system function**.

Systems thinking is an approach to thinking that includes the interactions and interrelationships among multiple and sometimes conflicting contexts. The basic idea of systems thinking involves moving away from a reductionist approach to learning and thinking to an approach that constantly refers to the “whole” system as the fundamental point of reference.

This implies that, the **performance of the system** depends on **how well the parts fit together**, not how well they perform individually. Thus, the best parts do not necessarily make the best whole; **they have to fit together** (for example football team) or a country political and economic system, or a business organization.

Simple analogy: Formula 1 Racing is system (enterpise) which has specific purpose to generate entertainment, generate revenue, encourages technological innovation by bringing to together teams (also systems that have system purpose to win as many races) **that provide racing cars that have specific system function.**

Paradigm to crumbling paradigm

A paradigm is a set of rules, written or unwritten, that sets the stage for a significant portion of society or a particular segment. When movement occurs between paradigms, the rules change, and if you don’t understand the change you get out of sync with reality. Paradigm Shifts are movements from one primary paradigm to another.

A paradigm according to Thomas Kuhn means a broad model, a pattern, a framework, way of thinking for understanding reality, behavior, and the rules within the system boundaries. Paradigm Shifts are movements from one primary paradigm to another. A paradigm is a set of rules, written or unwritten, that sets the stage for a significant portion of society or a particular segment. When movement occurs between paradigms, the rules change, and if you don't understand the change you **get out of sync with reality**.

A paradigm shift is a way of looking at something differently. We are stepping "outside the box". When we make a paradigm shift we can see, think, feel and behave differently. A paradigm shift is change from one way to another, revolution a complete transformation.

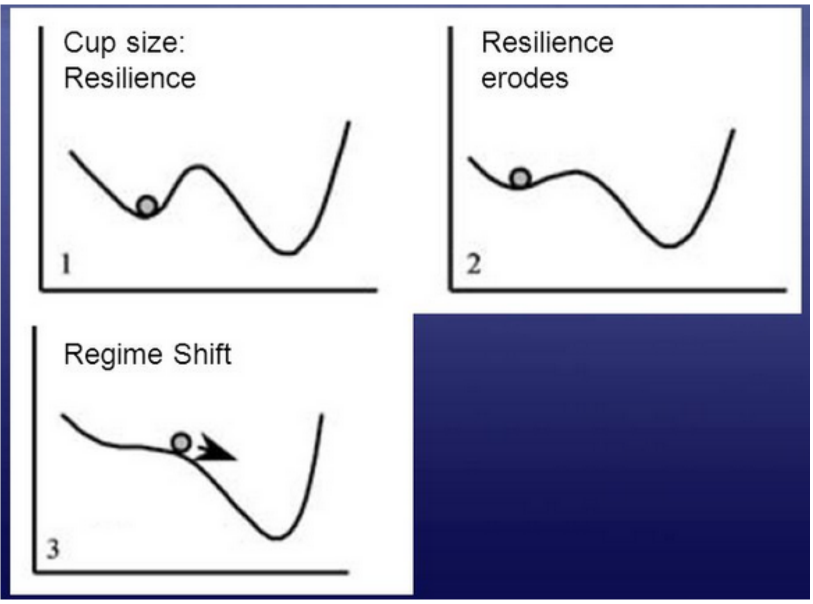
Paradigms are threatened by:

- Life changing events / threats
- Its model is questioned
- There is a design miss-match whereby aspirations are greater than resources
- Internal drive for systemic transformation

How are **paradigms formed**?

Paradigm Shift: When anomalies or inconsistencies arise within a given paradigm and present problems that we are unable to solve within a given paradigm, our view of reality must change, as must the way we perceive, think, and value the world. We must take on new assumptions and expectations that will transform our theories, traditions, rules, and standards of practice. We must create a new paradigm in which we are able to solve the insolvable problems of the old paradigm.

A '**crumbling paradigm**' is a condition in which an institution or industry has outlasted its operating assumptions. The condition is detected when the business or the mission results of an industry or a company within an industry are flat or declining while more and more resources are consumed. When this happens, the institution or industry goes into an irreversible decline until a new operating model takes its place. A new operating model implies a totally different system architecture (structure and relationship) and governance model .



Transformation is the process of starting or ending a paradigm (Paradigm shift) and involves a terminus. This terminus either triggers total collapse of an existing paradigm or a crumbing paradigm (digital cameras versus film and Kodak collapse)

Crumbling paradigms have a direct relationship with resilience stability landscape whereby system trajectory pathway progresses towards sequence of unfavorable regime with diminishing system performance potential.

Law of diminishing returns

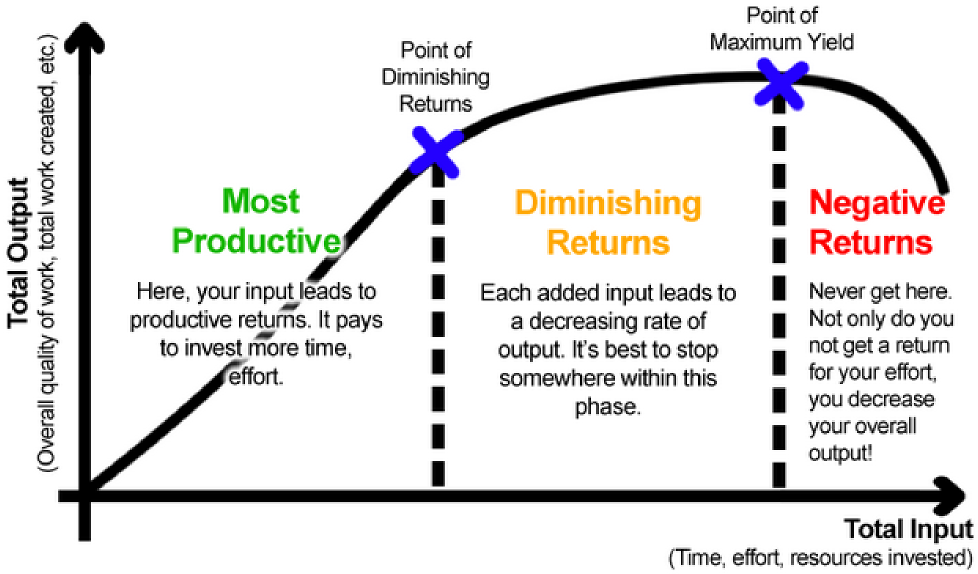
The law of **diminishing returns states** that as one input variable is increased, there is a point at which the marginal increase in output begins to decrease, holding all other inputs constant. At the point where the law sets in, the effectiveness of each additional unit of input decreases.

System dynamics is an approach to understanding the behavior of complex systems over time. **It deals with internal feedback loops** and time delays that affect the behavior of the entire system.

The **systems** are characterized by:

- **Structure** – composition of elements.
- **Behavior** – involved inputs, processes and outputs of material, energy and/or information.
- **Interconnections** – structural and functional relations between elements.
- **Emerging properties** – system properties that do not appear in individual elements.

Emergent attributes are the properties of the **whole, and only exists as a whole**, not a properties of the component bits. Emerging properties have a fundamental impact on the system performance and becomes extremely important to **understand behavior of variables trajectory** with respect to system state of diminishing or negative returns.

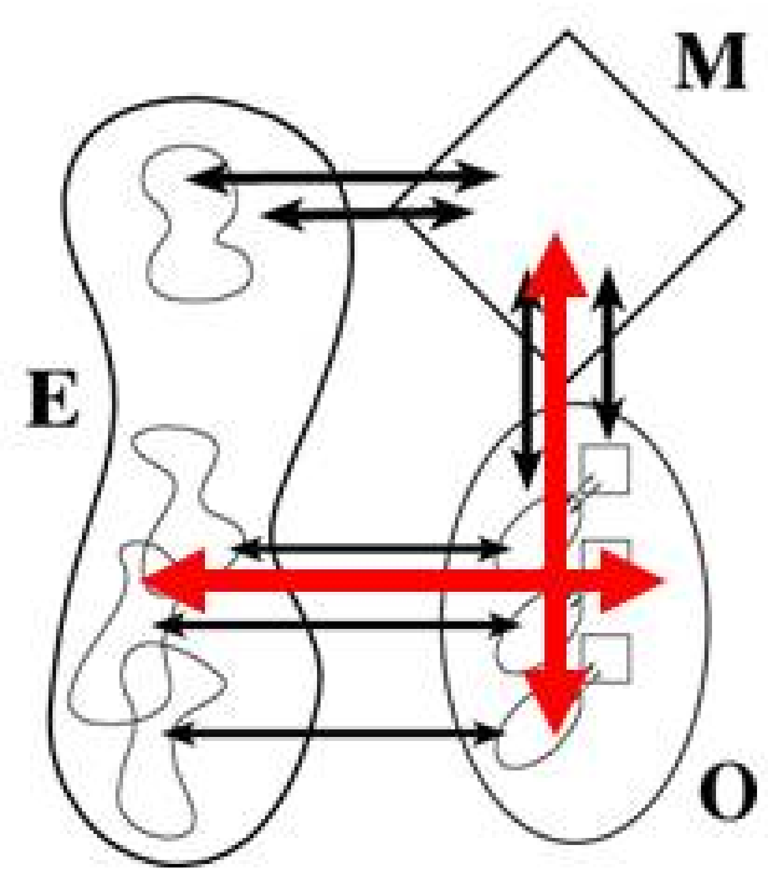


Systemic balance

All system have control systems in place that are characterized by the fact that they have goals: states of affairs that they **try to achieve and maintain**, in spite of obstacles or perturbations. Organizations define their own goals and strive to avoid deviation from this goal by applying ideal feedback. These goals the represent the system 'set course' against which the system is steered via its **governance** model. In order to be sustainable and viability it is then imperative that that primary goal and associated secondary goals are defined that ensure systemic viability. Key consideration with respect to systemic goals:

- Must contain subset of acceptable states.
- The dimensions defining these states are called the essential **variables**, and they must be kept within a limited range compatible with the survival of the system.

Viability is the capacity of a system (organization, company, state) to maintain a separate existence and identity over time despite changes in the environment. Sustainability is the ability of effectively manage its adaptive cycle (relevant system stage) key properties such as ideal system potential, its connectednnes (internal controls versus influence of external variables) and resilience by means of a dynamic governance model. By maintaining identify organization via its regulatory process that it will persist through a process, learning, adaptation and evolution by **ensuring homeostatic equilibrium**.



A system is homeostatic if it can maintain itself in a state of equilibrium under two conditions:

- In order to cope with the environment the operations needs to match its variety to that of the environment.
- In order to manage the operation management needs to match its variety to that of the operations.

Horizontal balance and vertical balance which cannot be mutually exclusive and requires cohesion between vertical and horizontal balance in order to attain optimum balance.

They key challenge is: ‘what’ is the optimum balance for a system and ‘how’ to determine the optimum balance.

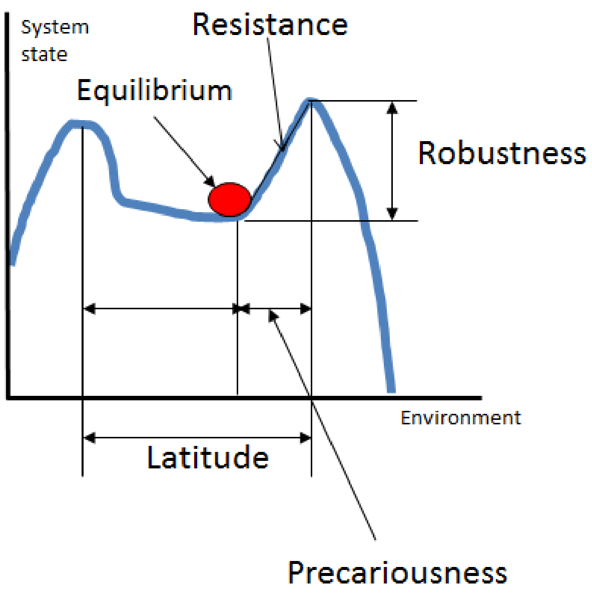
The ‘what’ and the ‘how’ is defined within Variety Engineering.

Resilience

About resilience

Resilience is the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks. Adaptability is the capacity of actors in a system to influence resilience.

The state space of system is the three-dimension space of all the **possible combination** of the **variables** that constitute the system. (Walker et al) and defines the maximum possible potential/performance. The state of the system at any time is defined by their current values.



A “basin of attraction” is a region in **state space** in which the system tends to remain and whereby maximum potential/performance is possible. For systems that tend toward equilibrium, the equilibrium state is defined as an “attractor,” and the basin of attraction constitutes all initial conditions that will tend toward that equilibrium state.

All real-world Social and Ecological Systems (SeS) are, however, continuously buffeted by disturbances, stochasticity (random variables), and decisions of actors (governors) that tend to move the system off the attractor. Therefore, there is a belief SeS are moving about (a marble whirling around a bowl) within a particular basin of attraction, rather than tending directly towards an attractor. There may be more than one such basin of attraction for any given system with different state space and performance potential; which may be more favorable or less favorable, of low or high resilience. The various basins that a system may occupy, and the boundaries that separate them, are known as a "stability landscape" and are separated by resilience threshold or tipping points.

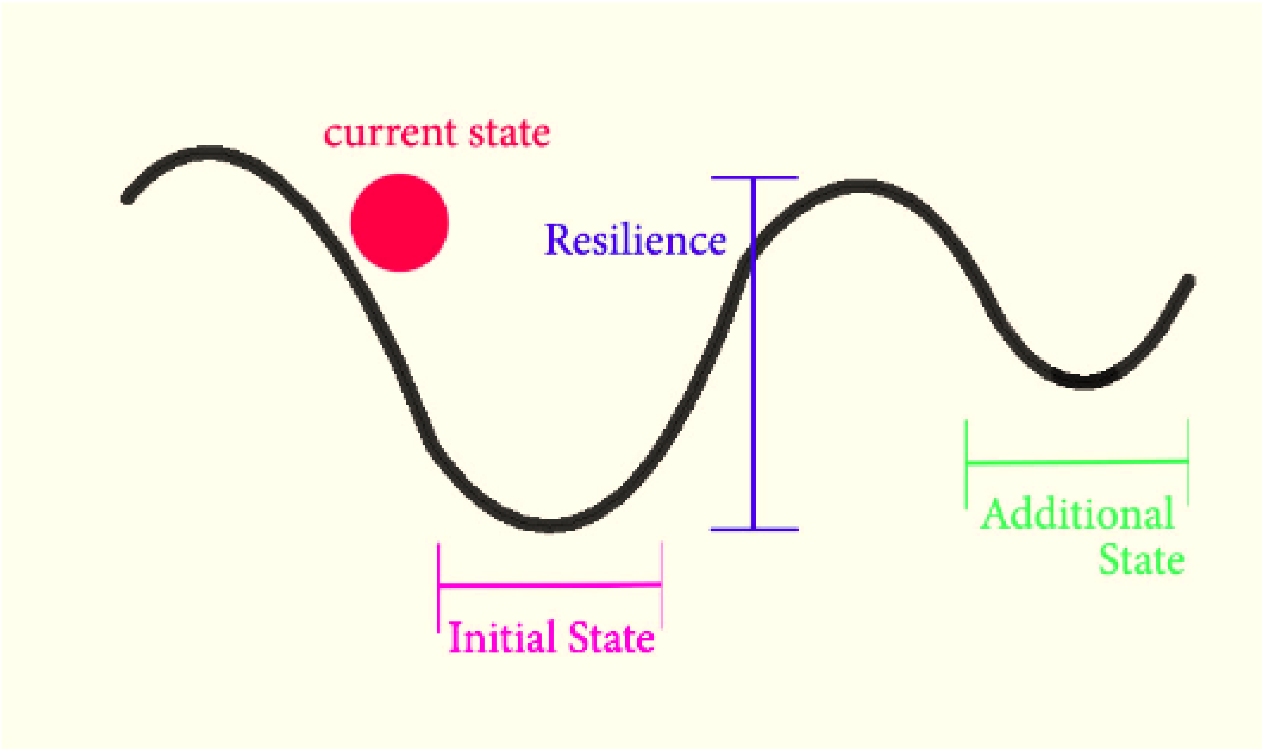
Both exogenous drivers (external drivers such rainfall, exchange rates, competitor value proposition) and endogenous processes (plant succession, management practices and governance efficacy) can impact resilience and its capacity to recover and restore its system performance potential.

There are four crucial aspects of resilience. The first three can apply both to a whole system or the sub-systems that make it up.

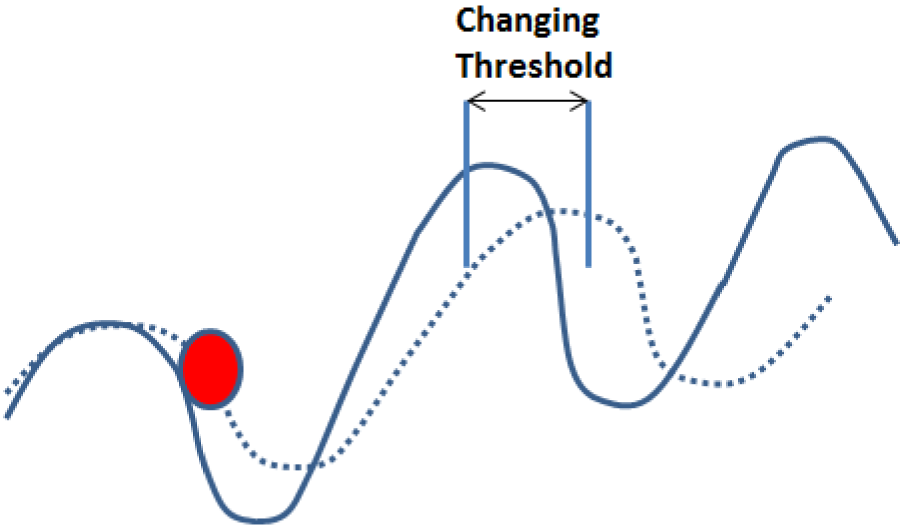
- **Latitude**: the maximum amount a system can be changed before losing its ability to recover (before crossing a threshold which, if breached, makes recovery difficult or impossible).
- **Resistance**: the ease or difficulty of changing the system; how "resistant" it is to being changed.
- **Precariousness**: how close the current state of the system is to a limit or "threshold."
- **Panarchy**: because of cross-scale interactions, the resilience of a system at a particular focal scale will depend on the influences from states and dynamics at scales above and below related systems). For example, external oppressive politics, invasions, market shifts, or global climate change can trigger local surprises and regime shifts.

Resilience is defined as the capacity of a system to tolerate disturbances without collapsing into a qualitatively different state so as to still retain essentially the same function, structure, identity, and feedback" (Brian Walker) even more important governing system adaptation 'of what to what'; recover system performance or govern the system towards a different state space. Resilience is not just about capacity to tolerate disturbances but fundamentally:

- Fully understating its state space.
- Its trajectory, basin of attraction and stability landscape.
- Its dynamics with basin of attraction and across regime.

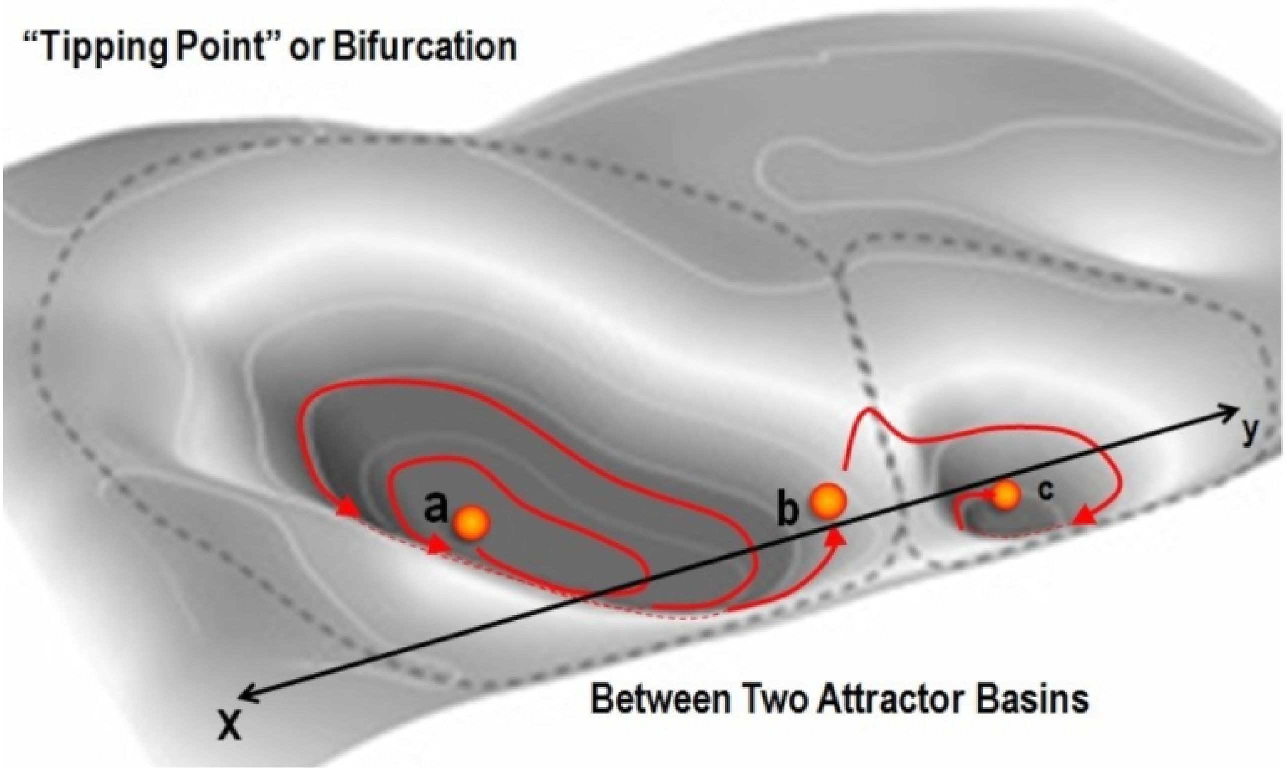


The greater the resilience is in a particular system the more it can resist large or prolonged disturbances. If resilience is low or weakened, then smaller or briefer disturbances can push the system into a different state, where its dynamics change. Disturbances such as outside disorder (environment) the system has to cope with and the internal state of the system itself.

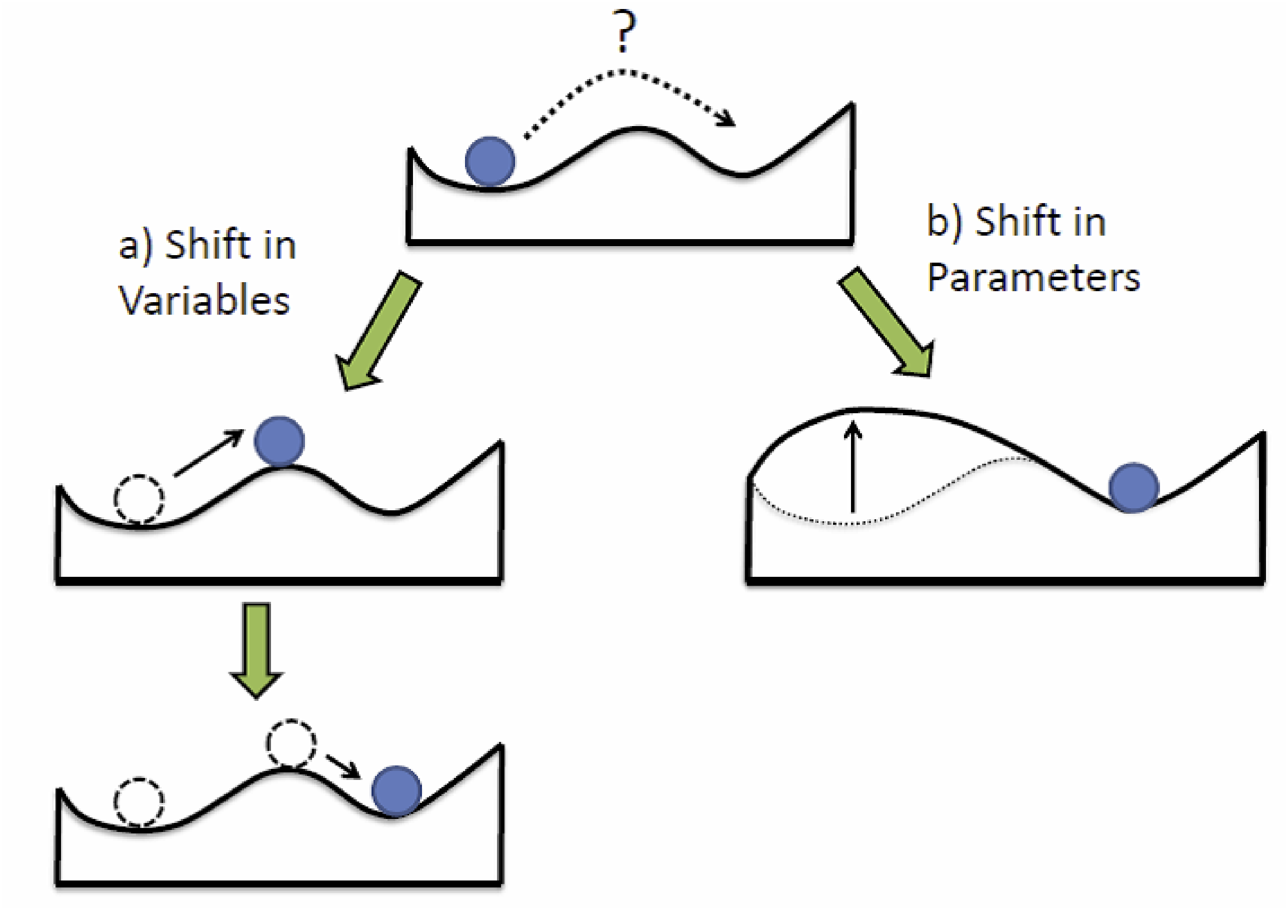


Once resilience is overwhelmed (resiliency threshold will be crossed) system enters a new state, restoration to original sate will be complex, expensive, and sometimes even impossible.

The ball represents the current state of the system, or the current configuration represented by the different states with same function and feedback, and is represented by system variables, e.g. the amounts of grass, trees, livestock, and people, un-employment, debt, production). The ball moves to its basin of attraction (bottom of basin is the equilibrium state = attractor) but also move elsewhere via its trajectory due to inner dynamics (governance efficacy and system performance) as well as external dynamics causing the basin to change shape specifically location of thresholds or tipping point (dotted line). After crossing the tipping point the system tends towards a different equilibrium (change in feedback that that drive the system dynamics) depending on basin shape and location of threshold.



When a system tips into a different basin or regime, that means a threshold is crossed. The change is sudden all in all (if one looks at the situation from the appropriate time scale), but that does not necessarily mean that the underlying (observable) variables have changed in such a sudden way. The change here can be quite slow and gradual, but once a certain value or amount is exceeded, different dynamics and feedbacks may set in which then cause the big/fast change or regime shift to happen. This of course has to do with feedbacks, the secondary effects of a direct effect of one variable on another, causing a change in the magnitude of that effect: **negative feedback loops** have a dampening effect (they tend to buffer or bring back to balance), **positive feedback loops** are reinforcing and have an enhancing effect (they cause exponential growth and may have runaway effect).



The basin of attraction can also be influenced by external factors these external factors are external elements that influence the definition of set of states or configurations with the same functions and feedback, so: with basically the same identity. In a real situation dynamic condition implies that concurrently resilience is influenced by both shift in parameters and shift in variables that **push the system in over tipping point into different regime** (favorable or unfavorable) and limits ability to recover from disturbance due to fragility.

After crossing this tipping point, the system tends towards a different equilibrium (because of a change in feedbacks that drive the system's dynamics). **The stability landscape consists of multiple or alternate possible sets of states or regimes**. Fundamentally controlled resilience is about capacity of a system to absorb disturbances and restoration to maximum performance / potential and still persist with same basic structure in order to avoid crossing critical performance thresholds and remain stable around attractor basin and maintain system identity.

Research suggests that to restore some systems to their previous state requires a return to environmental conditions and the same function, structure (resources), identity, and feedback well before the collapse. This can be seen why after prolonged economic crisis; growth has difficulty absorbing the unemployed labour force.

Where resilience is overwhelmed system may also reach extinction within the stability landscape rather than a new state. Example: Maya, the Romans, and Kodak.

Resilience can only be effectively managed by understanding its inherent structure and its dynamics. It's not just about managing recovery (performance levels) caused by disturbance but also understanding stability landscape, system trajectory and its momentum, thresholds in order for effective adaptation (doing the right things) and avoiding system collapse.

Resilience structure

Effective systemic governance of resilience implies understanding system state (**of what**) and governing resilience (**to what**), recovery of performance and governing resilience within existing basin or to a different favorable regime within the stability landscape. Therefore it is fundamental to understand resilience elements in order to govern resilience:

- The System
- Basin of attraction
- Threshold
- Regime
- System Performance with respect to resilience
- Resilience Stability Landscape
- Resilience Feedback
- Measuring Resilience
- Vulnerability and Resilience
- Resilience: Transformability

Resilience dynamics

Resilience is the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks.

Adaptability is the capacity of system to influence resilience, restore potential and mange disturbances considering diversity, system leadership, regimes, dynamics balance and scales.

While transformability is the capacity to create a fundamentally new system when ecological, economic, or social (including political) conditions make the existing system untenable (Paradigm Shift).

The challenge for system governors / entrepreneurs is how to take action that will shift the current system into a different basin of attraction or increase resilience to maintain stated performance potential. It is important to note that changes to a system are continuous (internal and external) and systems will crash and change (there is no eternity) The challenge is to ensure governance efficacy to guide and change (**adaptation transformability**) effectively without causing further damage and at the least possible cost considering system effects related to **Senge's 11 Laws of Systems**.

There are four crucial aspects of resilience. The first three can apply both to a whole system or the sub-systems that make it up with respect to function, structure, identity, and feedbacks.

There are four crucial aspects of resilience. The first three can apply both to a whole system or the sub-systems that make it up with respect to function, structure, identity, and feedbacks.

- **Latitude**: the maximum amount a system can be changed before losing its ability to recover (before crossing a threshold which, if breached, makes recovery difficult or impossible).
- **Resistance**: the ease or difficulty of changing the system; how "resistant" it is to being changed. Changes in the "depths" of basins, a measure of how difficult it is to move the system around within the basin — steep sides imply greater perturbations or management efforts are needed to change the state of the system.
- **Precariousness**: how close the current state of the system is to a limit or "threshold." Moving the system around changes its position within a basin relative to the edge or moves it into a new basin where, without the state of the system itself changing, the system finds itself in a new basin of attraction, owing to changes in the stability landscape.
- **Panarchy**: because of cross-scale interactions, the resilience of a system at a particular focal scale will depend on the influences from states and dynamics at scales above and below. For example, external oppressive politics, invasions, market shifts, or global climate change can trigger local surprises and regime shifts.

In Westley's words, "Where is the change you want to see"or 'from what to what'. In effect this is asking the question of **whether to work towards increasing or to reducing resilience**?

In order to effectively manage resilience dynamics, system governors have to ensure preparedness and learning capacity that can effectively manage disturbances, adaptation and transformation:

- **Viability**; dealing with complexity achieving optimum potentiality and system equilibrium (homeostatic).
- **Adaptability**; being flexible.
- **Transformability** being innovative.
- **Persistence**; being robust.

Resilience management is fundamental for long term sustainability and viability. From a system governance perspective the key is to manage resilience effectively by understanding, internal dynamics, resilience threshold, low and high resilience applicable for adaptation. Resilience governance entails clear understanding of:

- Understanding mechanism that act upon resilience:
  - Cumulative changes in systemic properties (environmental changes, viability, crumbling paradigms) that leads to a gradual loss of resilience.
  - An intense shock (earthquake, banking system, economic sanctions, Brit Exit from EU) that drastically changes the system state.
- Systemic Variables that have quantities that change "quickly" in response to feedback from model dynamics

Transformation Initiatives can only effectively managed by considering resilience dynamics. Resilience engineering can assist in managing disturbances effectively and providing guidance with respect to transformation efficacy; doing the right things to avoids possibility of undesirable situations where system cannot recover or leads to inferior system state.

Resilience in processing

When processing information and principles, any system can encounter highly dynamics or undefined variables which can drag the system's performance down due to its inability to process it or to carry it in an effective way. It happens in a lot of different scenario in both living and non-living systems which can effect the system's resilience, capabilities, and proper functioning such as causing malfunctions which can be part of helpful degenerative processes.

If you encounter a system with undefined variables which are needed for processing, a substitute or replacement can provide the sufficient means for a proper functioning/processing, such as changing the subject to being processed or to substitute it with feelings or interactions as for living systems.

System governance

Resilience management is fundamental for long term sustainability and viability. From a systemic governance perspective the key is to manage resilience effectively by understanding, internal dynamics, resilience threshold, low and high resilience applicable for adaptation. Resilience governance entails clear understanding of:

- **Understanding mechanism that act upon resilience:**
  - **Cumulative changes in systemic properties** (environmental changes, viability, crumbling paradigms) that leads to a gradual loss of resilience.
  - **An intense shock** (earthquake, banking system, economic sanctions, Brit Exit from EU) that drastically changes the system state.
- Systemic Variables that have quantities that change “quickly” in response to feedback from model dynamics

> **“System Governor’s action influence resilience, either intentionally or unintentionally.”**

Their collective capacity to manage resilience, intentionally, determines whether they can successfully avoid crossing into an undesirable system regime, or succeed in crossing back into a desirable one.

Fundamentally within resilience framework is to understand resilience the question ‘of what to what’ that investigates resilience in particular system contexts and configuration and to particular disturbances. Resilience engineering is about effective adaptation; doing the ‘right things’ to minimize manage, maintain performance and improve performance:

- **“where is the change you want to see?”** In effect this is implies governing the system **towards increasing or to reducing resilience or towards a totally new regime**.
- Is the existing system considered brittle, in a rigidity trap? Are there factors that may be keeping a system in a deep basin or could there be an opportunity for change?
- Restoring system performance within existing basin of attraction or equilibrium attractor an preventing undesirable regime shift.
- Effective adaptation governing regime shift by **guiding system trajectory** that cross threshold, understanding system context within the new regime basin of attraction in order to **maintain maximum performance potential and manage perturbation**.

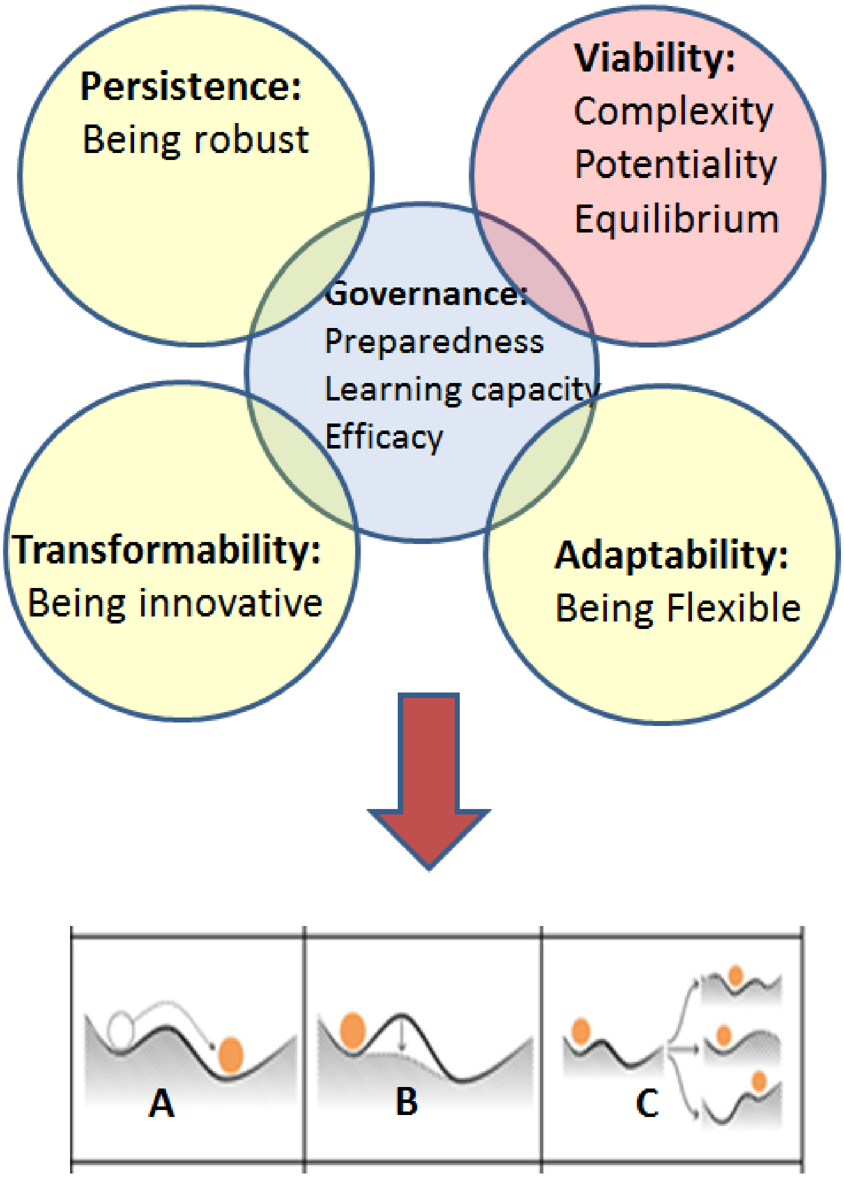
- Carrying out specific governance action to pilot change to basin of attraction (reduce resilience) and guide system to new favorable regime or create a totally new one (new industry paradigm). This new innovative alternative has to have adequate resilience in order to avoid reverting back to its old state or even worse regime. Systems can exhibit very strong qualities of remembrance and revert to earlier states as a matter of course. (cited in Westley et al., 2006)

This entails the ability of System Governors to either control the trajectory of the system (change precariousness), change the topology of the stability landscape (latitude and resistance), or **change the processes** in response to dynamics at other scales (panarchy response), is a measure of adaptability. **Both purposeful movements** between basins, and purposeful reshaping of the stability landscape, demonstrate adaptability. SeS's can move from one basin of attraction to another either by the system crossing a threshold, or by a threshold moving across the system.

System governors can intervene by increasing resilience which equates to lowering the new basin – making the new system more attractive, more stable, more likely to "stick" given a system shock. Alternatively, one might take the approach of reducing the resilience of the current system – effectively raising the level of the old basin.

- Move thresholds away from or closer to the current state of the system by altering **"latitude"**.
- Move the current state of the system away from or closer to the threshold **"precariousness"** or make the threshold more difficult or easier to reach **"resistance"**.
- Governors can manage cross-scale interactions to avoid or generate loss of resilience at the largest and most socially catastrophic scales **"Panarchy"**.

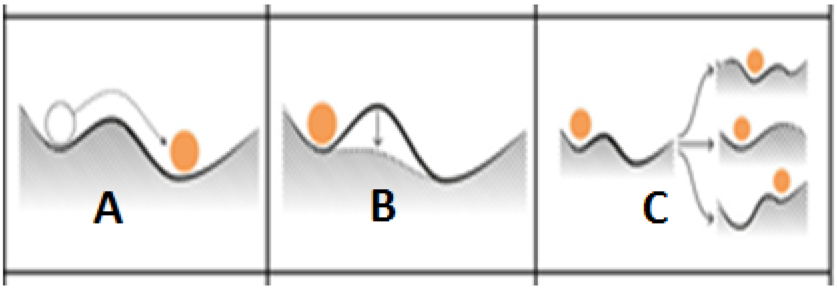
In conclusion, effective system governance needs to find a balance between adaptability, persistence and transformability:



Resilience is not only about the capacity of a system to tolerate disturbances without collapsing into a qualitatively different but to manage the resilience and system dynamics into different regime:

- New regime (window A) caused by shift in variables. Push system over the threshold into new regime.
- New regime (window B) caused by shift in parameters; lower the barrier (tipping point) caused by external conditions such as access or loss markets.

- Reconfiguration of the system (window C transformations) in fundamentally paradigm shift each in its own regime.



In a real world situation transitions to new regime are both influenced by shift in variables and shift in parameters. A system is a continuously influenced by changing variables and parameters due systemic conditions. **Reconfiguration** is either internally governed via effective adaptation whereby trajectory is controlled to tipping point that leads to ideal regime or due to overwhelming internal and external factors impacting system trajectory towards tipping point associated to less favorable regime.

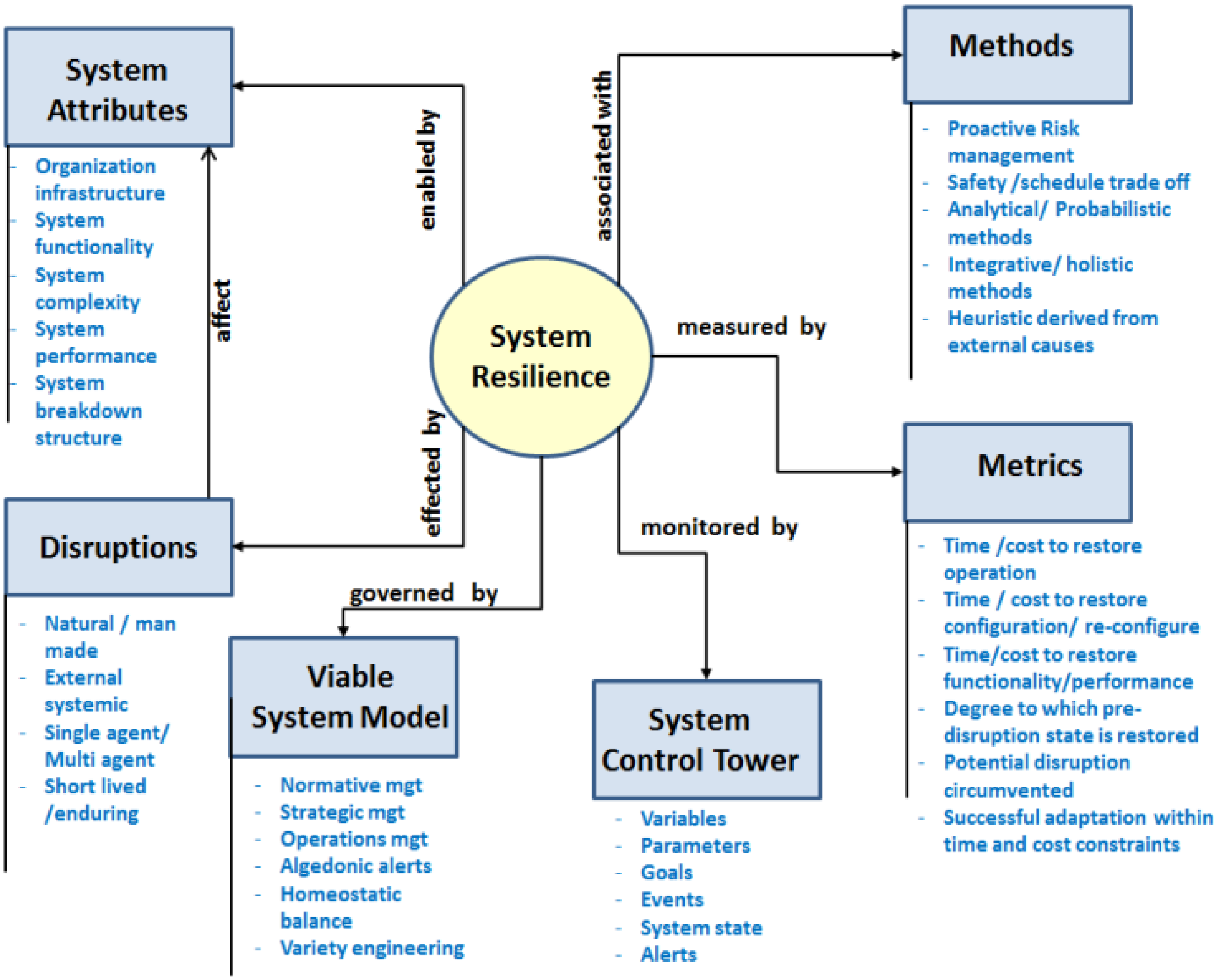
Effective resilience management “of what to what” cannot be viewed in isolation but rather as a sub-system of the whole; country economy is associated to the whole or fresh water basin as sub system to agricultural practice have a cross system effect impacting stability basin of the sub-system. It is important to bear in mind that “systems” consist of nested dynamics operating at particular organizational scales — “sub-systems,” as it were, of households to villages to nations, trees to patches to landscapes. Therefore managing resilience of the sub-system if of low efficacy without understanding the whole and the cross system effect; this is critical to do the right things.

No SeS can be understood by examining it at only one scale. The component of a SeS consists of groups of people organized at multiple levels with differing views as to whether some basins are desirable and others undesirable. At any particular scale, the system is actually a sub-system of the whole panarchy, and the first three aspects of resilience (latitude, resistance and precariousness) are influenced by what is happening in the panarchy at scales above and below the scale of interest. Panarchy, the cross-scale effects, is the fourth aspect of resilience that needs to be considered.

Resilience system governance framework

Resilience governance framework is not just about resilience but also viability, complexity mgt, variety and potentiality and understanding system dynamics.

In order to manage resilience effectively “from what to what” the following key elements need to be in place:


System Attributes
- Organization infrastructure
- System functionality
- System complexity
- System performance
- System breakdown structure
enabled by
associated with
Methods
- Proactive Risk management
- Safety /schedule trade off
- Analytical/ Probabilistic methods
- Integrative/ holistic methods
- Heuristic derived from external causes
affect
System Resilience
measured by
effected by
Metrics
- Time /cost to restore operation
- Time / cost to restore configuration/ re-configure
- Time/cost to restore functionality/performance
- Degree to which pre-disruption state is restored
- Potential disruption circumvented
- Successful adaptation within time and cost constraints
monitored by
Disruptions
- Natural / man made
- External systemic
- Single agent/ Multi agent
- Short lived /enduring
governed by
Viable System Model
- Normative mgt
- Strategic mgt
- Operations mgt
- Algedonic alerts
- Homeostatic balance
- Variety engineering
System Control Tower
- Variables
- Parameters
- Goals
- Events
- System state
- Alerts

- System definition
    - System attributes that define the systemic working of the system.
    - System metrics, variables and parameters.
- System governance model
    - Governance model based on Viable System Model that will include methods to deal with resilience, effectiveness, potentiality, constraints.
    - Algedonic alerts to identify potential disturbances / disruptions.
    - Variety engineering to deal with complexity.
    - System Control tower to monitor system performance, variables , events, disturbances.

The system

A system is a collection made up of the following entities:

- System elements.
- Relationship of system elements.
- Attributes (fixed and dynamic) of elements and relationship.

Both attributes and relationship are associated with variables (quantifiable variables and non-numerical). The system state at any time is the set of values held by the variables at that time. Any system has emergent properties that are possessed by none of its parts; each part has properties not possessed by the whole.

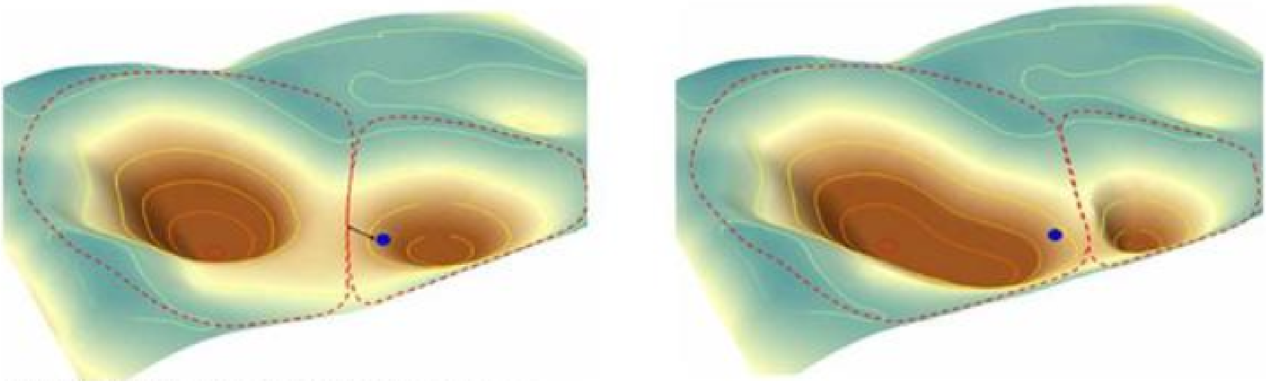
Social systems or **social structure** in general refer to entities or groups in definite relation to each other, to relatively enduring patterns of behavior and relationship within **social systems**, or to **social** institutions and norms becoming embedded into **social systems** in such a way that they shape the behavior of actors.

Complexity according to Schoderbek is a property of a system when examined from non-quantitative viewpoint is the product of the interaction of four main aspects:

- The number of elements; number of sub-systems contained in a system.
- Interactions between elements ; richness of the connectivity between these elements.
- Attributes elements and interactions; nature and features.
- Degree of organization; the extent that which the interactions and attributes are guided by predefined rules.

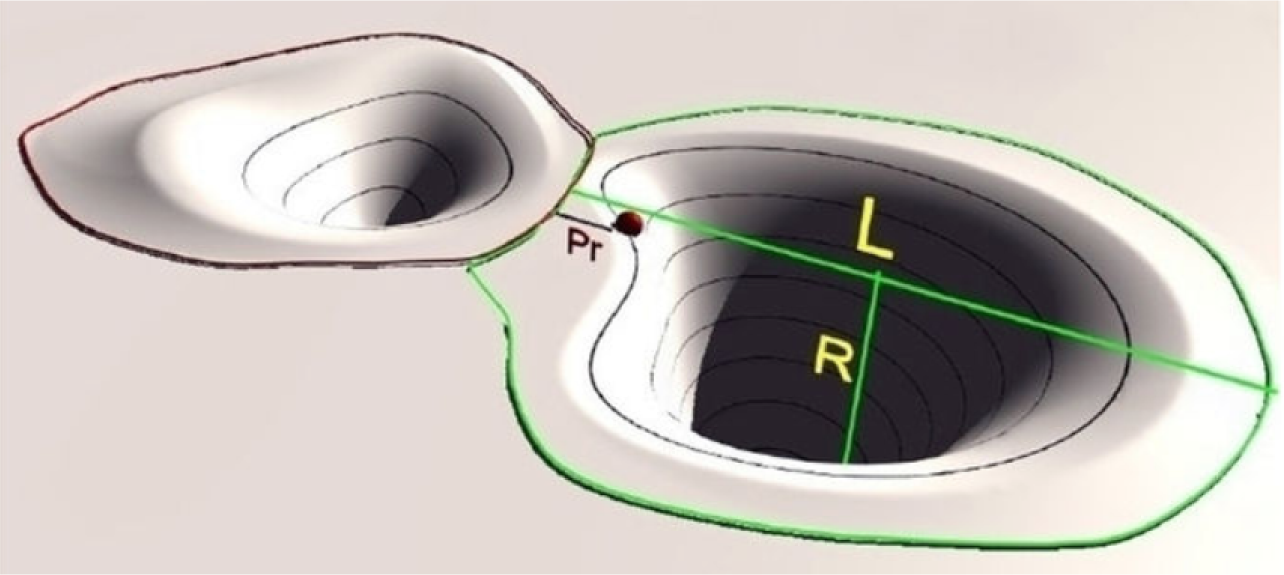
Basin of attraction

As defined by Walker1 et al., “a ‘basin of attraction’ is a region in state space in which the system tends to remain (2004). In this basin of attraction system achieves its maximum possible performance based on combination of its state sets.



The basin is a set of states or configurations with the same functions and feedback: with basically the same identity. What is called a regime (or set of system states) is an identifiable configuration of that system with characteristic structures, functions, feedbacks, and therefore, identity that tend towards equilibrium; the equilibrium state is defined as an ‘attractor’ in maintaining its stated performance. The basin acts as a basin of attraction: as long as the ball is in the basin (black dot), the system is in that regime; so a particular basin coincides with a particular regime.

The characteristics of the basin of attraction (the three aspects of resilience) is defined as three dimensional topography that has quantitative representation of **relief** (vertical and horizontal dimensions), usually using contour lines (of a function of two variables is a curve along which the function has a constant value, so that the curve joins points of equal value). While the black dot represent system state and its trajectory along the contour lines. In this three-dimensional framework the map is comparable to the effect of gravitational fields Einsteinian space (Walker, et al., 2004).



Three-dimensional basin of attraction is represented by:

L = latitude, the maximum amount system can be changed before losing its ability to recover

R = resistance, the ease or difficulty of changing the system

Pr = precariousness; the current trajectory of the system and how close it is currently to its "threshold" or "tipping point"

Different basins exert force that can attract the system. This is critical when looking at how to move to a different, desired, system state. It may be difficult to get from "here to there" without dropping into an unwanted state due to its attractiveness and resilience.

Fundamentally the states of the system within the basin of attraction represented by:

- System.
    - System elements.
    - Relationship of system elements.
    - Attributes (fixed and dynamic) of elements and relationship.
    - Both attributes and relationship are associated by function called variables.
    - Performance associated to variables.
- Function and purpose; the function and interaction of each sub-systems in achieving its purpose.
- Feedback.
- Identity; characteristics of system elements associated with sub-system and it properties.

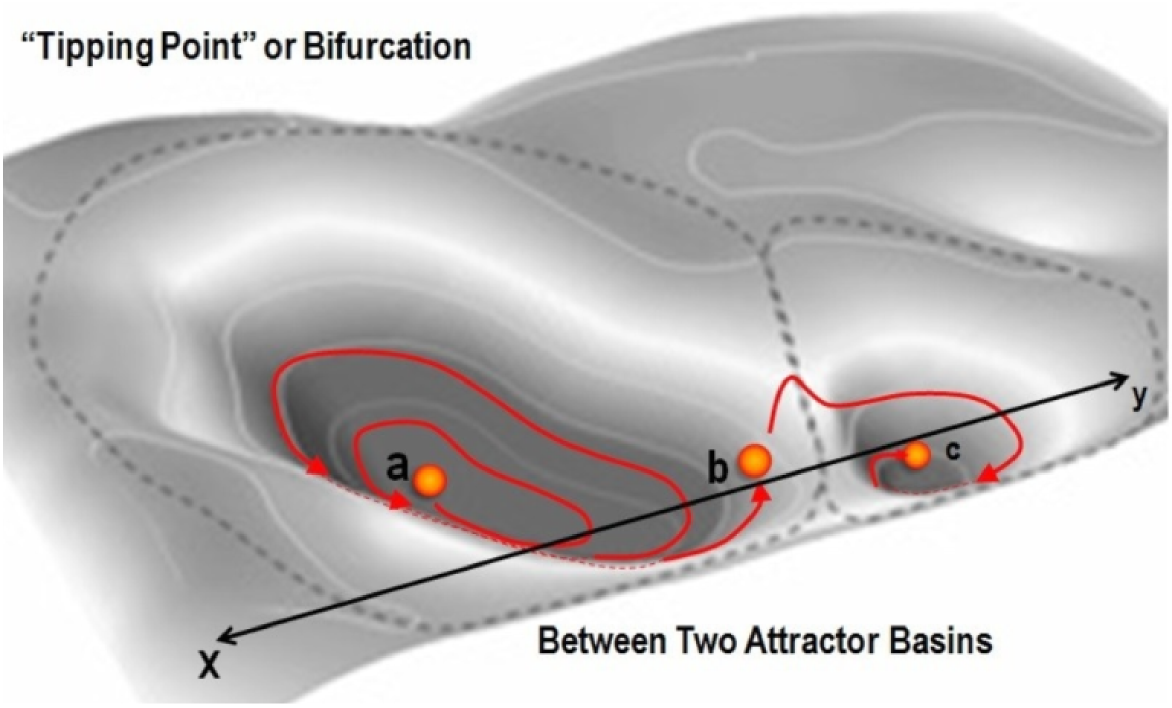
Threshold

Threshold is represented by contour lines (of a function of two variables is a curve along which the function has a constant value, so that the curve joins points of equal value) which is considered the breakpoint or tipping point between two or more regimes, levels in underlying controlling variables of a system in which feedbacks to the rest of the system changes, the change in dynamics is sudden while the change in observable variables can be slow or fast. Threshold gradient represents that limit whereby system set of states or configurations are possible and from 3 dimensional perspective may have different heights that lead to different regimes.

When a threshold along a controlling variable in a system is passed, the nature and extent of feedbacks change, such that there is a **change in the direction in which the system moves**. A shift occurs when internal processes of the system (rates of birth, mortality, growth, consumption, decomposition, leaching, etc.) have changed such that the variables that define the state of the system begin to change in a different direction, towards a different attractor. In some cases, crossing the threshold brings about a sudden, large and dramatic change in the responding variables, whilst in other cases the response in the state variables is continuous and more gradual.

The threshold levels (tipping point) indicate the natural progression of a system to different basin of attraction (regime). Some consideration with respect to thresholds:

- Systems are complex adaptive systems that may have multiple basins of attraction and limited predictability.
- When crossed thresholds between multiple basins of attraction can lead to fundamental transformations in system feedbacks and dynamics.
- Managing resilience specifically recovery from disturbance is important, even more important the focus on threshold boundaries that may have major consequences to performance potential when crossed.
- Thresholds can be used to screen or rule out actions that have a high risk of crossing into unfavourable basin; recovery in certain cases might require extreme effort and resources.
- Resilience engineering focuses on critical thresholds for system performance, if current basin (current situation is desirable) then govern the system towards increasing resilience, build capacity to recognize and respond emerging conditions/disturbances before they occur and finally build capacity to adapt should transformation occur.



- Systems trajectory dynamics tend to move towards least favorable basin

Disturbances can cause system state to shift **"trajectory a"** and either remain within resilience threshold or its resilience threshold is overwhelmed (resilience tipping point) **"trajectory b"** moving to a new resilience threshold as shown in system **"trajectory c"** which has totally different **function, structure, identity, and feedback**. Current system sates with its potential / performance can either be superior or inferior to previous system state: all depending on the resilience threshold.

Regime

Regime or basin of attraction is equivalent to state or set of states that a system can exist in with its characteristic system structure, function, feedbacks and identity. The system can be in alternate regimes with desirable or undesirable states/regimes whereby its desirability based on **collective human attitude, expectation and point of view**.

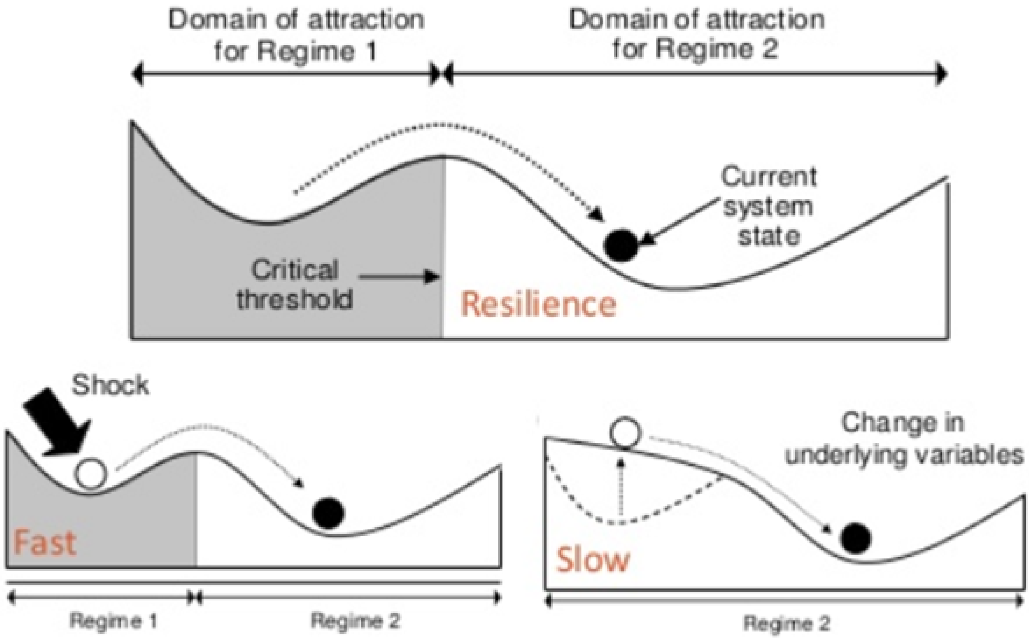
A regime shift means that after crossing a threshold, the system suddenly reorganizes or tips into a new situation/regime with different set of structures, functions, feedback and identity.

In social innovation terms, a basin of attraction would represent the current state of a system regime. Westley et al. define a regime as "the dominant rule-sets supported by incumbent social networks and organizations and embedded in dominant artefacts and prevailing infrastructures, of say, particular industries or social problem arenas." (2011).

In this three-dimensional framework the map is comparable to the effect of gravitational fields Einsteinian space (Walker, et al., 2004). Different basins exert force that can attract the system and in turn the different basin shapes are continuously influenced by external factors. This is critical when looking at how to move to a different, desired, system state. It may be difficult to get from "here to there" without dropping into an unwanted state due to its attractiveness and resilience characteristics.

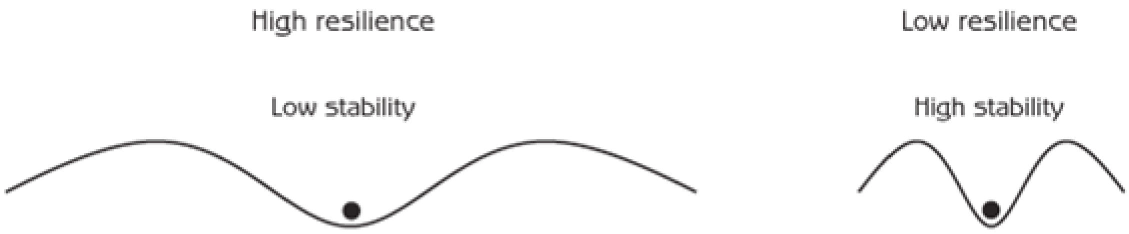
Regime shift is when a system crosses a threshold into an alternate regime of that system; the function structure and processes differ from the one in the old regime. This implies that the system moves from one dynamic / relative equilibrium to another tipping into (undesired or desired) states with different potential / performance characteristics.

Crossing back might prove difficult or simply impossible.


Domain of attraction for Regime 1
Domain of attraction for Regime 2
Current system state
Critical threshold
Resilience
Shock
Fast
Regime 1
Regime 2
Change in underlying variables
Slow
Regime 2

High-low resilience

Resilience threshold can be of either of low resilience or high resilience. From a systemic perspective they can be seen as negative or positive from systemic perspective: the key aspect is to understand within the adaptive cycle the ideal resilience needed.



High resilience provides low stability and facilitates the move to a system state that is part of a different threshold. Less disturbance (internally or externally controlled or externally) is needed to push the system into a new resilience.

How fast and large are resilience threshold shifts?

Critical consideration; slow variables determine the resilience of a system. The temporal and spatial dynamics of threshold shifts depend on the main processes causing feedbacks that affect variables of the system:

- Slow variables

Factors that slowly in response long-term processes and that constrain response of fast variables. Measurement of slow variables often require techniques that differ from those used to measure fast variables:

- Fast variables

Factors that change rapidly and that are mostly easily measured by managers. Rhey are often focal variable for managers.

They are difficult to ascertain loss of resilience due to high variability. Fast variables are generally those of concern to systemic situation, like crop production, Sales and gdp.

Is it possible to reverse resilience threshold shifts?

Sometimes it is possible to restore a degraded system into its former state, but it is often difficult, slow and expensive. Hence, threshold shifts are of major policy relevance and justify a precautionary approach to reduce the causes of resilience loss but also a proactive approach to enhance systems resilience.

Today, the main drivers of environmental change are land-use change, climate change, pollution, over-exploitation and invasive species. The threat posed by these drivers is aggravated by their cumulative effects but also by the possibility of interactions between the effects.

How can we prevent resilience threshold shifts?

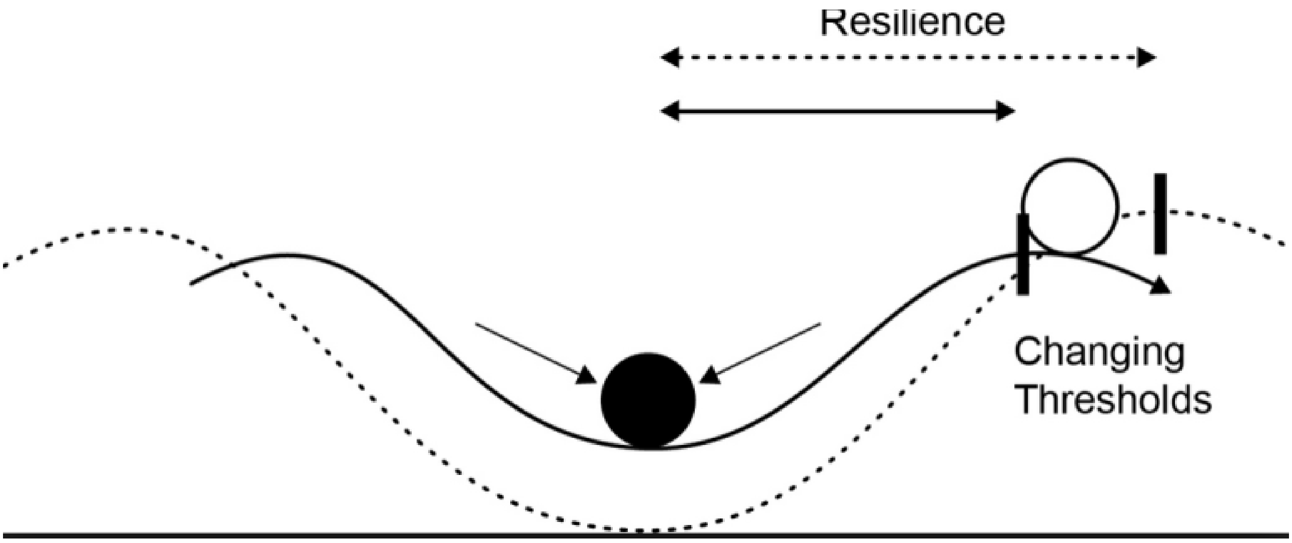
Preventing a pending threshold shift requires addressing the various pressures impacting a system at the scales in which they act, global (external to internal) to local.

- **Control local pressures** to increase the resilience to global scale drivers. Global scale dynamics are difficult to predict and manage and reaching international consensus is often challenging, therefore, controlling local pressures, which are more amenable to management, is essential.
- **Improve the adaptive capacity of social systems**. Informed, flexible and inclusive decision-making is needed to react timely to system feedbacks. This requires knowledge sharing, learning from past experiences, and the ability to move from business-as-usual unsustainable pathways to innovative forms of human-nature interaction.
- **Improve knowledge on threshold shifts.** This should be an overarching goal, including scientific research continued development of threshold shift databases, technology development, and educational outreach.

System performance

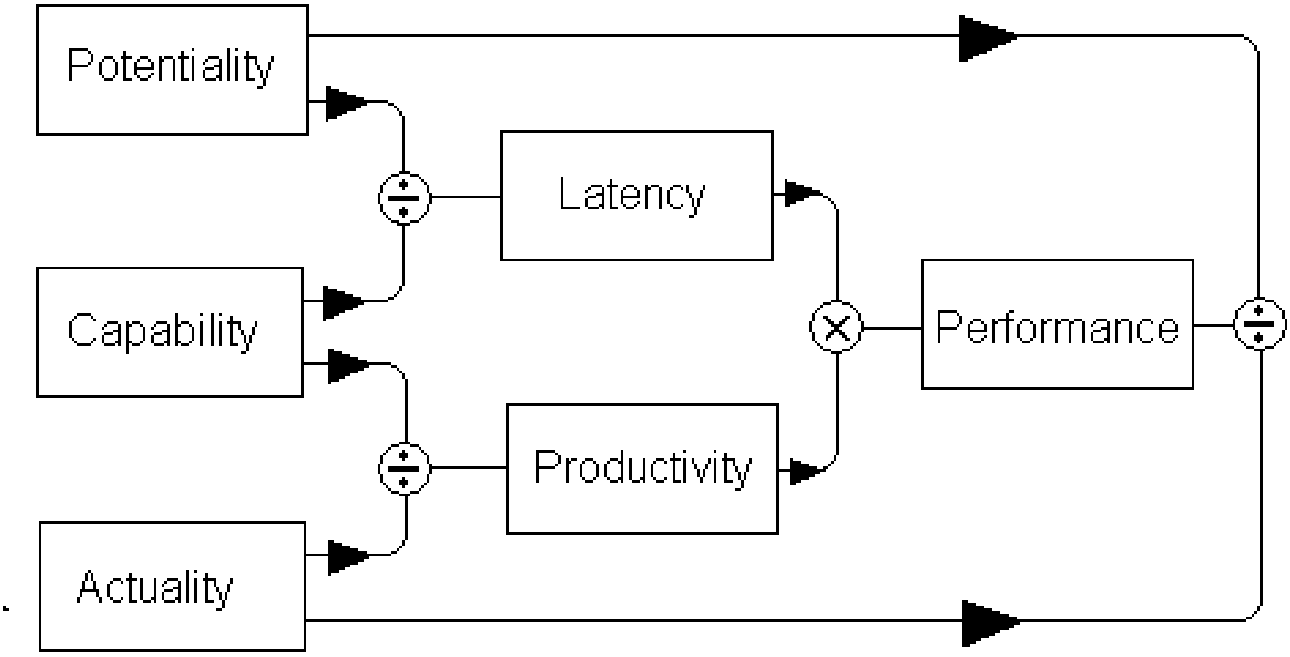
System Performance with respect to resilience.

The ball represents the current state of the system, or the current configuration represented by the different states with same function and feedback, and is represented by system variables, e.g. the amounts of grass, trees, livestock, and people, un-employment, debt, production). The ball moves to its basin of attraction (solid black ball bottom of basin is the equilibrium state = attractor) but also move elsewhere via its trajectory due to inner dynamics. The trajectory caused by disturbance impacts the potential / performance of the system.



Within a basin of attraction the system configuration generates a certain theoretical potential/performance. From a resilience perspective the trajectory reaches maximum performance (100%) at the bottom of the basin which is considered equilibrium state.

Once consideration of System Performance is based ratio between actuality (actual performance) and potentiality of the defined system configuration within the basin of attraction. **Therefore all system with proper governance can achieve maximum potentiality.**



Potentiality: This is what system should be doing within the boundaries of existing system state (same function, structure, identity, and feedback's) by developing its existing resources and removing constraints or elevating constraints to maximize **throughput** , efficacy with respect to control and processes although still operating within the bounds of what is already known to be feasible.

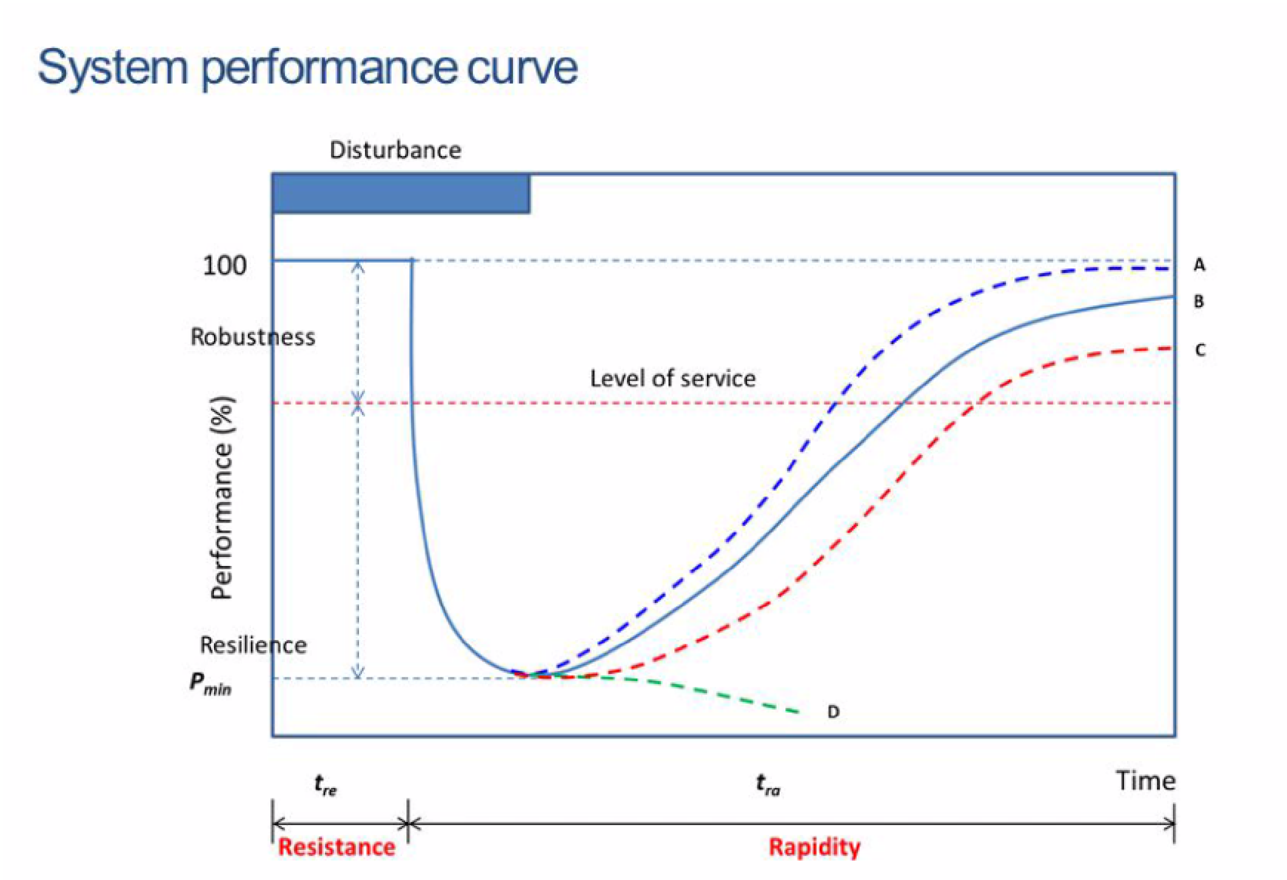
Capability: This is what system should be doing (still right now) with existing resources, under existing constraints, if there is management focus to eliminate waste, increase output resulting in improvements in productivity and efficiency.

Actuality: present way of managing the system, with existing resources, under existing constraints and exiting governance framework.

From resilience perspective, there following considerations apply:

Low internal efficacy in reaching potentiality impacts basin shape and may accelerate trajectory over tipping point to unfavorable basin while achieve high levels of potentiality will result in a more resilient basin which able to absorb disturbances.

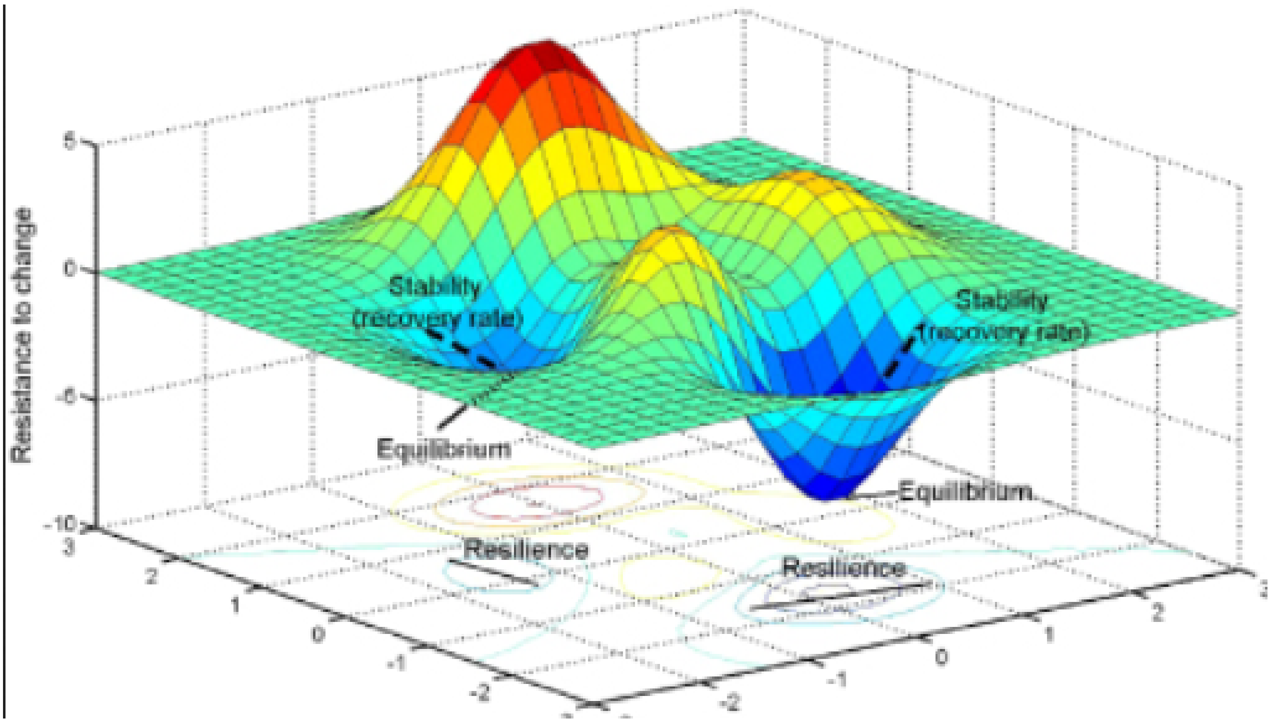
Disturbances impact performance whereby its system state is represented by trajectory that either crosses tipping point/threshold or recovers to its performance potential. Rapidity combined with basin shape will depend on system recovery. The greater the resilience in a particular system the more it can resist large or prolonged disturbances. If resilience is low or weakened, then smaller or briefer disturbances can push the system into a different state whereby previous performance potential will not be recovered. Recovery of performance (return to previous regime) will require substantial resources.



Response and recovery of system performance has to be done within time frame that avoids reaching tipping point. Recovery should reverse trajectory towards its basin of attraction (equilibrium state or attractor) with effective governance and at the same time it may modify its basin of attraction due to system states changes. Disturbances are also fundamental to understand potential opportunities that allow system transformation to migrate to a more favorable regime (paradigm shift).

Stability landscape

A stability landscape is multidimensional state space and represents all possible state variables in a system (Walker et.al 2004). Within this state space lie attractors of many sizes and shapes representing different stability characteristics. In the case of equilibrium attractors these locations are known as basin of attraction (3 dimensional state space) corresponding to qualitatively quasi-stable states a system may inhibit. The size and shape of the basin of attraction indicates the resilience of the corresponding state and its ability to withstand disturbances and adapt to main maximum performance with resilience threshold. The state space is dynamic therefore its topography is continuously fluctuating (changes in parameters and variables) which may affect the coordinates of the basin threshold (location and height). When perturbed a system may escape the attractor, cross the threshold and reach alternate state (new regime) which results in a functional change and a different set of controlling processes and performance capacity. The state space within a stability landscape may not be continuous as windows of opportunity or disaster may open or close (new basin of attraction) and some alternate states may not be directly reachable from current state of the system.



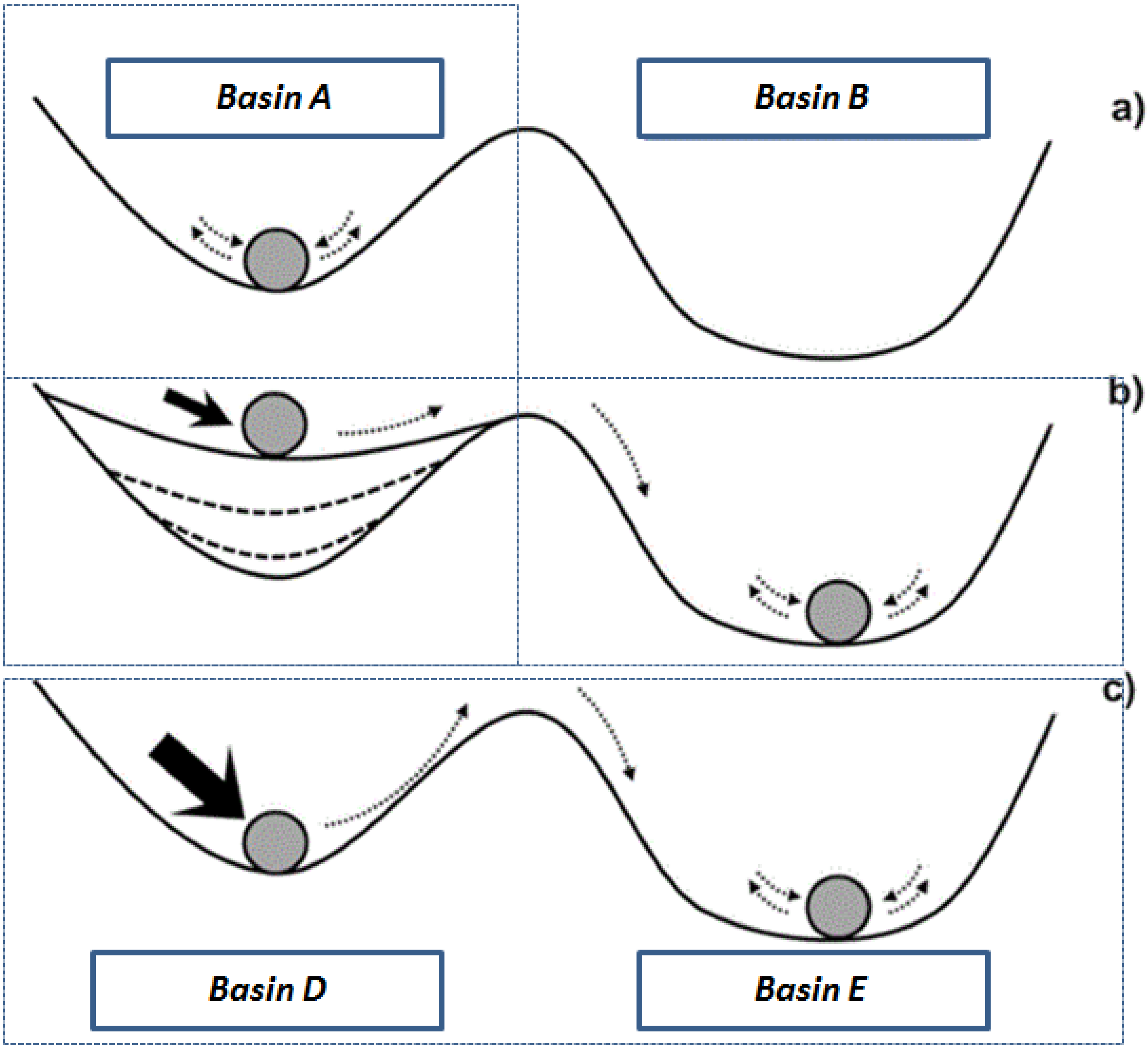
Industry paradigm which represents a window of opportunity that opens a new basin of attraction within it stability landscape and at the same time influences other stability landscapes by triggering perturbation (new industry paradigm may causes a crumbling paradigm).

Resilience stability landscape contains multiple possible regimes with its equilibrium, resilience, tipping points and contains possible pathway (good or bad) depending on the efficacy of adaptation. The associated regimes are not endless; tipping points can lead to nothingness (extinction). The basin of attraction are also influenced by external conditions related other system; example an economic system of a country stability landscape is influenced by another country stability landscape and other factors. An organization that creates new industrial paradigm will influence the stability landscape of its competitor. Resilience and therefore stability landscape topography is dependent not solely on system configuration but also on the perturbations of interest. Regime shifts (a what to what) that result from movement of a system from one basin to another are dependent on the type, magnitude an timing of perturbations as well as the cumulative effects of multiple disturbances and the rate system recovery (Scheffer at all.2001 Folke et al.2014).

The landscape can be influenced internally (management abilities, historical resilience behavior, systemic potential) and externally conditions (environment, business competition).

Changes in the stability landscape may result in a contraction of the basin the system was in and expansion of the alternate basin. These changes are influenced by exogenous drivers; where a new industry paradigm based on innovation and or transformation of one organization can influence stability landscape of the system.

Mechanisms driving resilience shifts can be depicted using “stability landscapes”: valleys represent stability domains, or basins of attraction, in which a system, represented by the ball, in (BASIN A) is kept by internal feedback mechanisms in equilibrium (fig a) cumulative changes in system variables can lead to a gradual loss of resilience, here represented by changes in the depth of the valley (fig b Basin A) that becomes shallower up to a point where even a small disturbance can push the system into a new basin of attraction, under a different threshold; (fig b Basin A to Basin B) an intense shock can also push the system into a new resilience threshold (fig c Basin D to Basin E).



When a system shifts into a new reliance threshold, it reaches and is kept in a new state by internal feedback dynamics characteristic of that resilience threshold (Basin B or Basin Eas). This makes the recovery to the previous regime very difficult, especially when lag effects in the system's response hinder its recovery.

In some cases resilience threshold shifts are mediated by tipping points, that is, a non-linear evolution of the system, where an additional small change causes the passing of a threshold and leads to an abrupt change (relatively to the baseline system dynamics). These tipping-point dynamics result from reinforcing feedbacks that amplify the impacts of the drivers of change.

Feedback

Feedback occurs when outputs of a system are routed back as inputs as part of a chain of cause-and-effect that forms a circuit or loop. The system can then be said to feed back into itself. The notion of cause-and-effect has to be handled carefully when applied to feedback systems:

Simple causal reasoning about a feedback system is difficult because the first system influences the second and second system influences the first, leading to a circular argument. This makes reasoning based upon cause and effect tricky, and it is necessary to analyze the system as a whole.

> Positive and negative feedbacks occurs for the very reason described above in which the system could have a stronger robustness and higher sensibility therefore reducing the need for large-scale feedback in for which the system can have pre-programmed meta-feedback prediction which can provide more viability for a system. The viability can be defined by the pattern of autonomy which is designed by the very (meta-)feedbacks to which viability depends on.
>
> In other words, **lighter feedback can be used if the sensibility of the system is increased** meanwhile, **providing a system many meta-feedback can programs predefined decision** which replace the need for many feedback and act as a small predicting algorithm. It therefore increase viability and **round-up systemic state update costs**.

Causality (also referred to as **causation**, or **cause and effect**) is the natural efficacy that connects one process (the cause) with another process or state (the effect), where the first is partly responsible for the second, and the second is partly dependent on the first. In general, a process has many causes, which are said to be causal factors for it, and all lie in its past. An effect can in turn be a cause of, or causal factor for, many other effects, which all lie in its future.

Self-regulation occurs in both the organization and its environment and is consequently of major importance: Self-regulation generates a degree of stability but if intervention is undertaken either in an organization or by an organization in its environment stability may be disturbed. If the causality (circular casual chains) have not been adequate understood then the intervention may produce unmanageable instability or pushing the system to a new regime due to crossing the resilience threshold.

The following order feedbacks are possible:

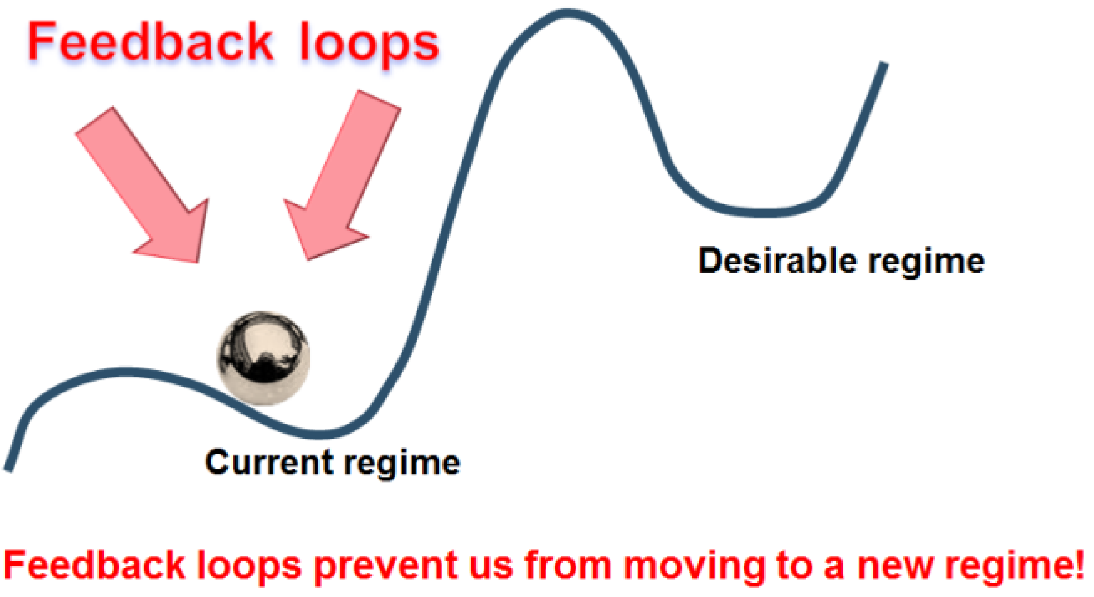
Simplest form of feedback where two elements continuously interact with each other such that the output of one determines the next action of the other:

- Negative or goal seeking behavior, the system will resist disturbances that take it away from its goal (equilibrium within basin of attraction). This is to say that the reaction of the one element is to inhibit the change in the other or vice versa.
- They are first order system that is the goal of the system determined externally to it.
- Opposite to negative feedback there is positive feedback whereby deviation by one element will be amplified rather than reduce by action of another.

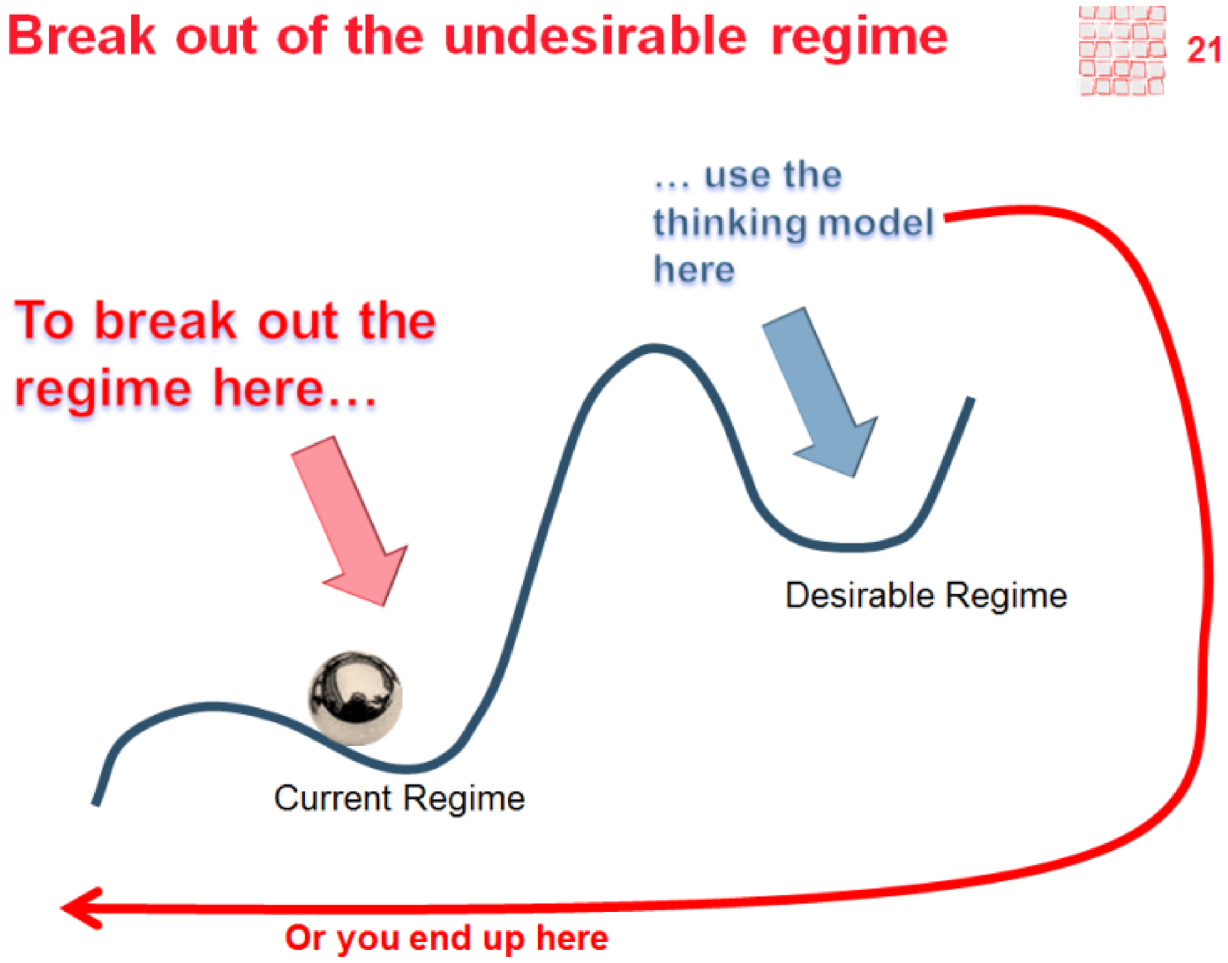
A second order feedback system is capable of choosing between a variety of responses to environment changes in order to achieve its goals.

A third order system is still more sophisticated in that it is capable of changing goal state itself in response to feedback process determining the goal internally as opposed first and second order systems.

Ultimately systems that include feedback loops are capable of demonstrating exceedingly complex behavior and large changes in that behavior may be brought about by small changes in the internal relationship.



And;


Break out of the undesirable regime
21
... use the thinking model here
To break out the regime here...
Desirable Regime
Current Regime
Or you end up here

Measuring resilience

Resilience is the capacity of a system to pro-actively and positively manage disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks.

A system made up of elements which provide essential services which are vital for a system to remain viable and sustainable and satisfy its purpose (function, structure, identity, and feedbacks). Critical system resilience is determined by the system ability deliver essential service at maximum performance in the event of disruptive incidents, by how it absorbs and recovers from those disruptive events.

System resilience capacity consists of:

- **Absorptive capacity**
  It is the capacity to take intentional protective action and to cope with known shocks and stress. Simply stated this is the capacity to 'bounce back' after a shock. It involves anticipating, planning, coping and recovering from stress and known shocks. Absorptive

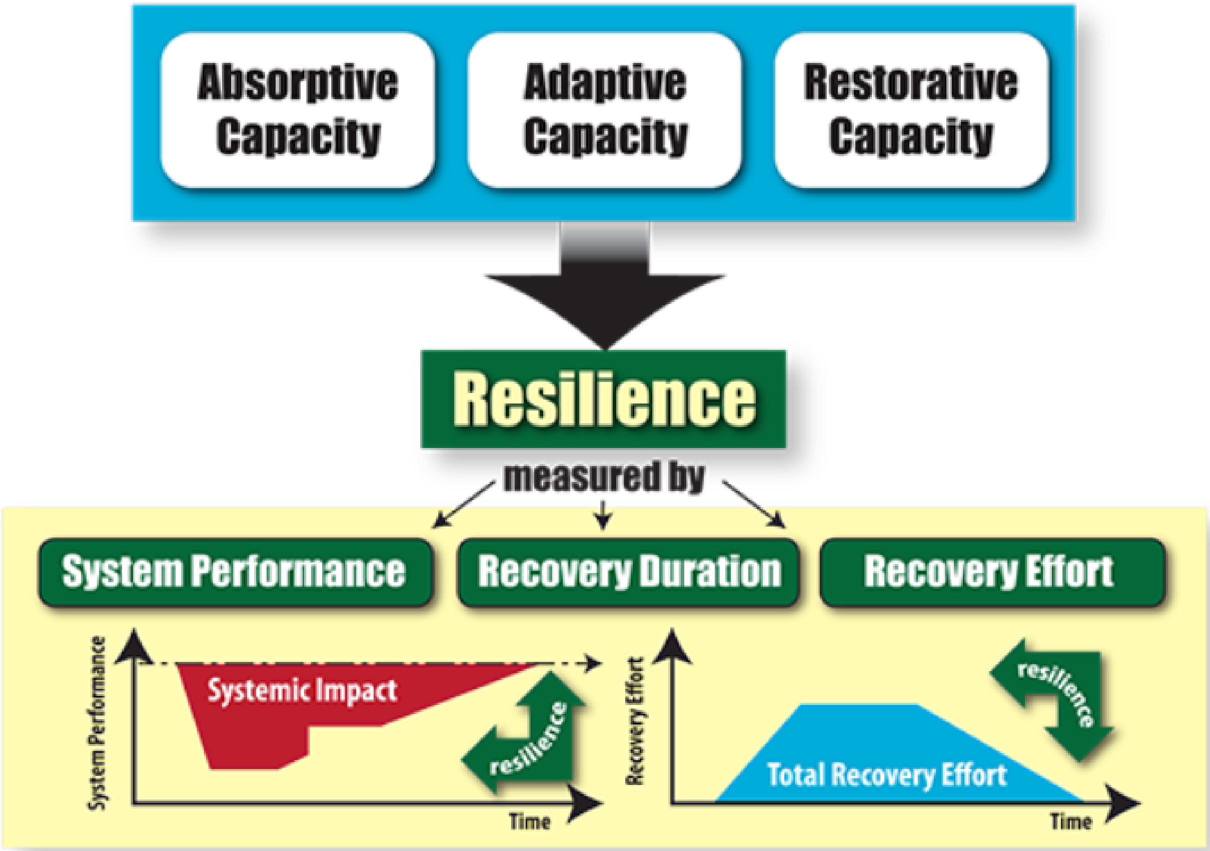
capacity is about ensuring stability and maintenance of the possible maximum performance.

- **Adaptive capacity**
  This is the capacity to make intentional incremental adjustment in anticipation of or in response to change in ways that create more flexibility in the future. Adaptive capacity is about flexibility and the ability to make incremental changes on ongoing basis through process of continuous learning, adjustments and innovation: fundamental to dynamic changing systems.
- **Restorative capacity**
  This is the ability of system to be repaired easily, efficiently and can be considered as the last line of defense because it requires the greatest amount of effort and in not normally applied unless absorptive and adaptive capacities are not able to maintain an acceptable level of performance. In most instances restorative capacity is needed when system is broken and unable to perform. Restorative capacity involves repairs that are implemented with the goal of returning to a system something near its original structure; if possible depending on stability landscape, trajectory and tipping points.

A key differentiator is that restorative capacity directly impacts Total Recovery Effort (resource usage) whereas abortive and adaptive capacity primary effect the cumulative System Impact on System Performance and may reduce recovery duration and effort thereby reducing System Impact.

Repairs to the system enabled by restorative capacity impact System Performance (drain) and may reduce recovery duration by reducing System Impact.

While adaptive capacity reflects ability of a system to be changed endogenously (within regime or basin of attraction), restorative capacity and involves changes that can radically alter structure of the system (new regime) to restore System Performance or even enhance System Performance (transformation).



Resilience can be measured as follows:

- Theoretical Maximum System Performance (TMSP); variables:
  - Theoretical Maximum System Performance defined by maximum system potentiality of the current regime.
  - Percentage maximum TMSP
  - Value TMPSP variables (currency, units)
  - Actual System Performance (ASP); variables (currency, units)
  - System impact variables linked to TMSP
- Recovery;
  - Time / cost to restore operation
  - Time / cost to restore configuration/ re-configure
  - Time / cost to restore functionality / performance
  - Degree to which pre-disruption state is restored

  - Potential disruption circumvented
  - Successful adaptation within time and cost constraints

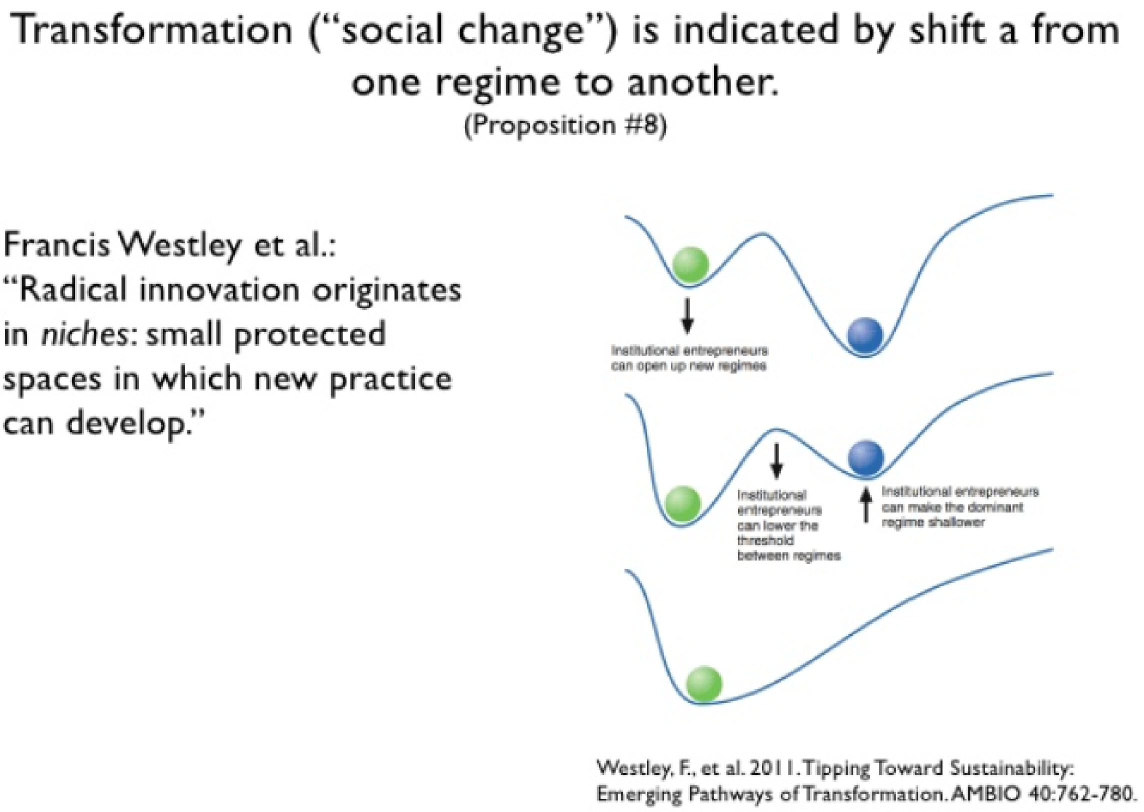
Vulnerability and resilience

Vulnerability has been defined as the degree to which a system, or part of it, may react adversely during the occurrence of a hazardous event. This concept of vulnerability implies a measure of risk associated with the physical, social and economic aspects and implications resulting from the system's ability to cope with the resulting event. Concepts of resilience take two broad forms, namely:

- Hard resilience: the direct strength of structures or institutions when placed under pressure. In the disaster context, resilience is often treated as the simple inverse of fragility. Engineers, for example, often refer to increasing the resilience of a structure through specific strengthening measures to reduce their probability of collapse with respect, for example, to earthquake intensities, wind loading or other physical stresses. As resilience increases, the degree of damage for a given intensity hazard decreases.
- Soft resilience: the ability of systems to absorb and recover from the impact of disruptive events without fundamental changes in function or structure.

Transformability

The capacity to create a fundamentally new sub-system when ecological, economic, or social, political conditions, crumbling industry paradigms (Kodak film) conditions make the existing system untenable (Paradigm Shift). At times or organizations may find themselves trapped in an undesirable basin with low system performance that is becoming so wide, and so deep, that movement to a new basin or sufficient reconfiguration of the existing basin becomes extremely difficult. At some point, it may prove necessary to configure an entirely new stability landscape — one defined by new state variables, or the old state variables supplemented by new ones. The capacity to create such a new stability landscape is known as transformability — the capacity to create untried beginnings from which to evolve a new way of living when existing ecological, economic, or system structures become untenable. New variables are introduced or allowed to emerge.



Transformation ("social change") is indicated by shift a from one regime to another.
(Proposition #8)

Francis Westley et al.:
"Radical innovation originates in *niches*: small protected spaces in which new practice can develop."

Institutional entrepreneurs can open up new regimes
Institutional entrepreneurs can lower the threshold between regimes
Institutional entrepreneurs can make the dominant regime shallower

Westley, F., et al. 2011. Tipping Toward Sustainability: Emerging Pathways of Transformation. AMBIO 40:762-780.

The changes cascade through and may transform the whole panarchy with all its constituent adaptive cycles. There are many examples of systems becoming locked in and unable to transform until it is too late (collapse, extinction); the wrong 'of what to what'. Knowing if, when, and how to initiate transformative change, before it is too late to escape a seriously undesirable and deepening basin of attraction, is at the heart of transformability.

A tension will exist between maintaining the resilience of a desired current configuration in the face of known (and some unknown) shocks, and simultaneously building a capacity for transformability (paradigm shift), should it be needed.

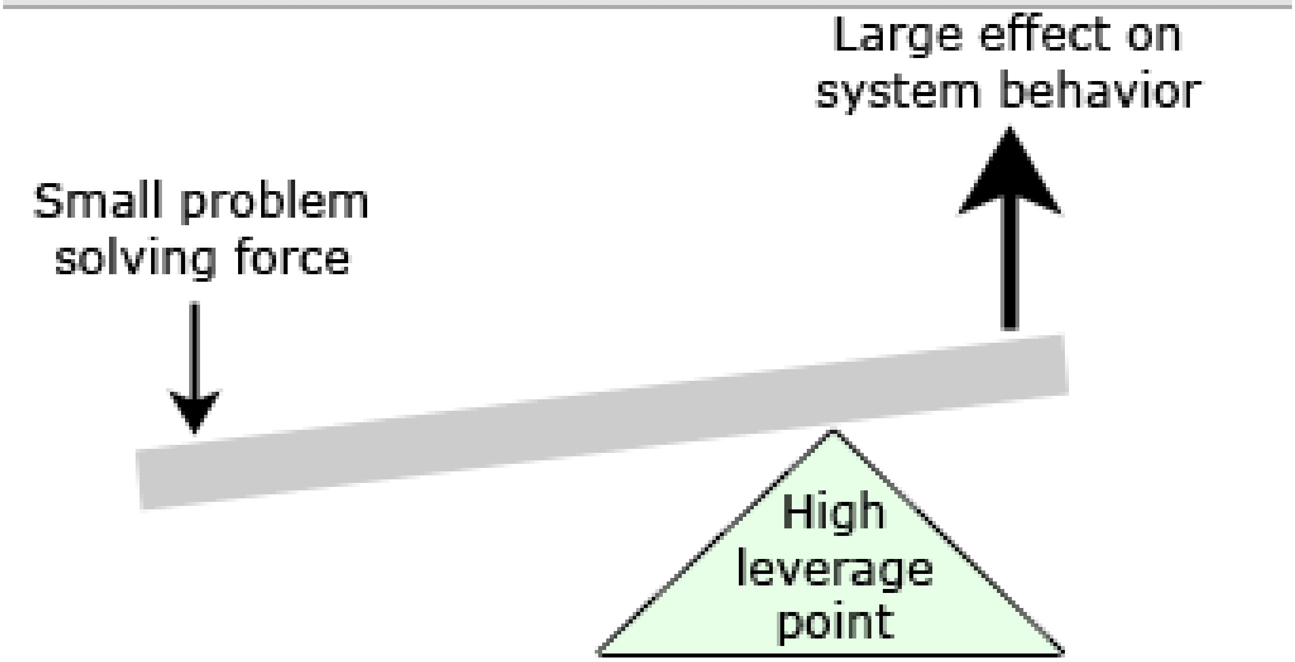
It is nevertheless likely that there is overlap in the attributes that promote adaptability and transformability. In addition to such common attributes (e.g., diverse and high levels of natural and built capital), attributes required for transformability will emphasize novelty, diversity, and organization in human capital — diversity of functional types (kinds of education, expertise, and occupations); trust, strengths, and variety in institutions; speeds and kinds of cross-scale communication, both within the panarchy and between other systems elsewhere.

Leverage

Effectiveness and **efficiency** are attained through interaction of the sub-systems in pursuit of the **purpose** of the system in its environment. The goal of sub-systems is concerned with the purpose of the system and the means of achieving that purpose:

- The human sub-system deals with the people and their management and motivation
- The technical sub-system handles the operations (input-transformation-output) with the aid of human sub-system
- Managerial sub-system co-ordinates and manages each of the others balancing their relationship and attending to environmental relationship to ensure viability

A System is a whole, which consists of interdependent and interacting elements with a single purpose. A system is greater than the sum of its elements. When a system is taken apart it loses its value and so do the parts.

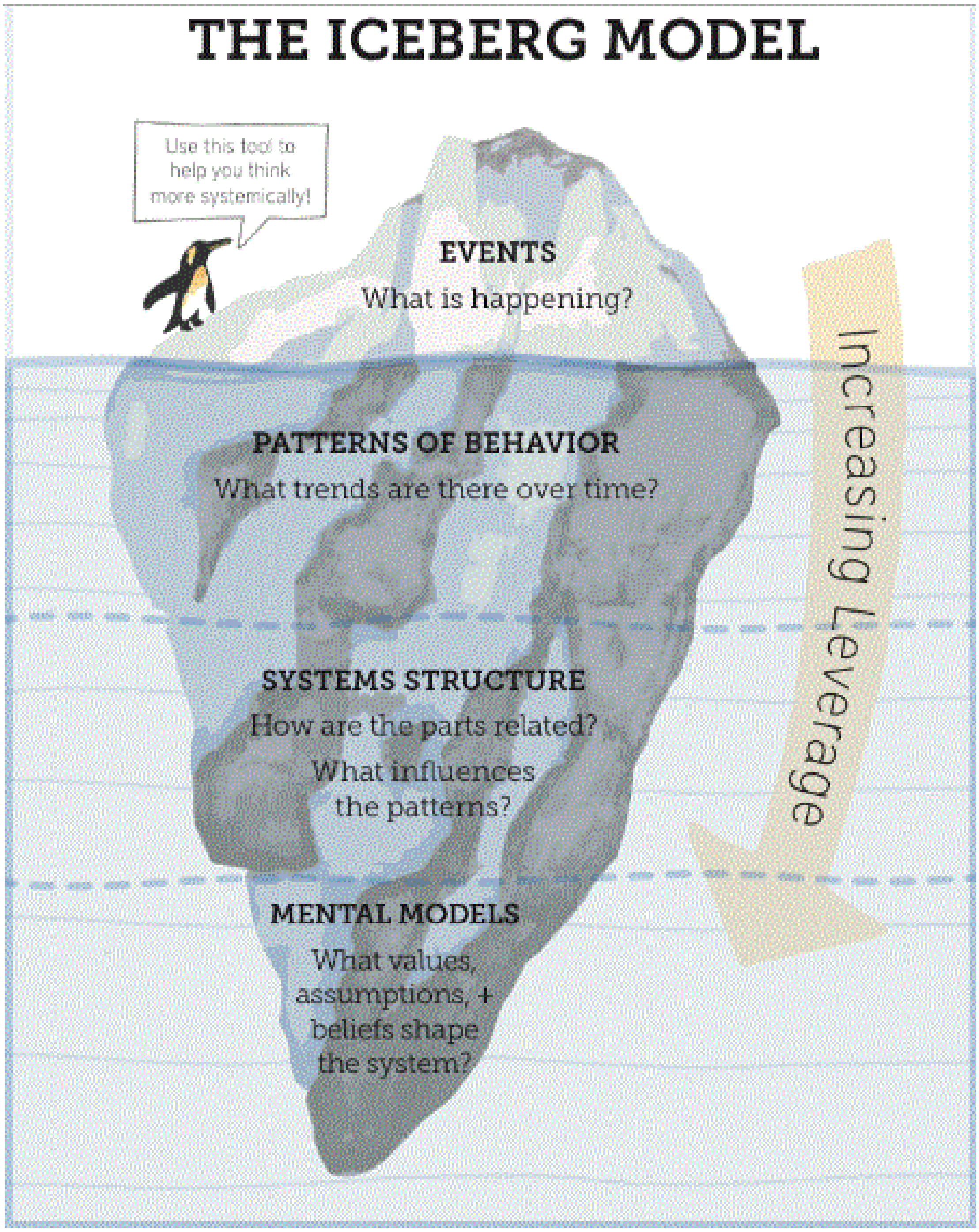


The implication of all this is that performance of the system depends on how well the parts fit together, not how well they perform individually.

A system being a whole cannot be leveraged but rather places within the system need to leveraged in order to create changes. Types of leverage differ in terms of relevance and importance depending on the system that requires change. An economic system requires leverage points whose relevance and priority will differ to say an organization like Kodak or Blackberry.

System or business transformation is about putting into place a process of continuous and effective leverage. Effective implying relevance of the leverage points that maximize system benefit.

The following approach is fundamental in achieving increasing leverage:


THE ICEBERG MODEL
Use this tool to help you think more systemically!
EVENTS
What is happening?
PATTERNS OF BEHAVIOR
What trends are there over time?
SYSTEMS STRUCTURE
How are the parts related?
What influences the patterns?
MENTAL MODELS
What values, assumptions, + beliefs shape the system?
Increasing Leverage

- **Events**
  What is happening in the system over time in relation to key variables system state.
- **Patterns of Behavior**
  Prior to undertaking a leverage exercise, it is critical to understand the system and its behavior.
  Leverage is found during analysis of modeling results, by exploring positive or negative behaviors (dominant influences with respect to connectors and flows), looking for sources of pressure and imbalance that cause things to change, and determining changes to structure, so that behavior is improved and bad events become less frequent. Each model structure represents logic that determines behavior, and events are snapshots of that behavior:
  1. An event is an occurrence or happening of significance to our understanding of complex system behavior.
  2. A behavior pattern is something that connects together a long series of events over time.
- **System Structure**: is the set of physical and information interconnections that generate behavior that determine how the parts are related and understanding what influences the patterns.
- **Mental Models**: Understanding what values, assumption and beliefs shape the system behavior in achieving its purpose and minimizing possibility of costly errors in intervening in complex systems.

In the language of system dynamics, important system variables are represented as stocks, flows, and feedback loops. Stocks are the accumulations points in a system. Simple examples of stocks are water that accumulates in a bathtub, accumulations of product inventory, or money that accumulates in a bank account.

With respect to leverage; adaptability conditions are fundamental to identify the right leverage applicable (the right thing to do) in order to maximize potential, potentiality and capability.

Adaptability and adaptive cycles

The term **adaptation** is used in biology in relation to how living beings adapt to their environments. Flexible systems are those that improve performance (or chances of survival / viability) by monitoring and adjusting its own configuration and operations in response to feedback from its environment.

Adaptability is the **ability of a system** (e.g. company/organization/state) **to adapt itself** efficiently and rapidly to changed circumstances by means of transformation and innovation. An adaptive system is therefore an open system that is able to fit its behavior according to changes in its environment or in parts of the system itself.

A system at any point in time consists of 3 critical interrelated elements where their properties and that determine system sustainability state:

- **Potential**: sets the limits to what is possible – the number and kinds of future options available
- **Connectedness** : determines the degree to which a system can control its own destiny through internal controls, as distinct from being influenced by external variables
- **Resilience**: determines how vulnerable a system is to unexpected disturbances and surprises that can exceed or break that control

All systems experience dynamic **adaptive cycles** which are based on the properties / dimensions of the the key sustainability elements and will determine a certain system state: **exploitation** (rapid growth), **conservation stage** (system reaches carrying capacity and stabilizes), **decline / extinction** and **reorganization**. Each of the adaptive cycles requires adaptive governance that is able to effectively recognize the specific adaptive **cycle sate** (three dimensions) and must tailor its governance model so that its **adaptation triggers** initiative that maximizes the three sustainability elements optimally.

A system that is the decline / extinction phase requires a governance model that minimizes damage and is able to swing across to the reorganization sates with minimal costs to the system by applying the **correct adaptation initiative**.

In it dynamic condition, system internal and external variables experience system state , they have trajectory based on its dynamic behavior. Furthermore, system have properties that that determine its adaptive cycle due its characteristics. Form a system governance not only steering is about course correction based on variable system state but also adopting management action based on the applicable adaptive cycle and its relevant **dynamic characteristics** in order to initiate effective management action.

Adaptive governance realizes that change is neither continuous and gradual, nor continuously chaotic. It is episodic (consisting of a series of separate parts or events), regulated by interactions between fast and slow variables.

Adaptability therefore forms the foundations for **Systemic Governance / Steering** by steering towards set-course of know system; or adaptation of set-course (new set-course) by means of transformation and innovation. System governance implies also understanding:

- Behavior; from a content perspective **System dynamics** is an approach to understanding the behavior of complex systems over time. It deals with internal feedback loops and time delays that affect the behavior of the entire system.
- Adjustment: from a context perspective ensure homeostatic state of equilibrium within horizontal balance and vertical balance which cannot be mutually exclusive.
    - In order to cope with the environment the operations needs to match its variety to that of the environment.
    - In order to manage the operation management needs to match its variety to that of the operations.

Viability

About viability

Cybernetics is a multidisciplinary approach for exploring regulatory **systems**, their **structures**, **constraints**, and **possibilities**.

Cybernetics is relevant to the study of systems, such as mechanical, physical, biological, cognitive, and social systems. Cybernetics is applicable when a system being analyzed incorporates a feedback loop; that is, where action by the system generates some change in its environment and that change is reflected in that system in some manner (**feedback**) that triggers a system change, originally referred to as a “circular causal” relationship.

Cybernetics is a way of thinking that recognizes the ‘whole’ system exhibits emergent properties that are not to be found in its parts. These emergent properties determine system potential, viability and resilience.

Cybernetics as with the whole of the system tradition takes its starting point with the “input > transformation > output “ model. This reflects the idea that the system carries out some activity, the transformation and is open, i.e it imports ‘instructions’ (information) and acts upon those instructions (governed by management) to produce an output within the environment in which system is embedded.

Management cybernetics is the application of cybernetics to management and organizations. “Management cybernetics” was first introduced by Stafford Beer in the late 1950s. Beer developed the theory with respect to system viability using the Viable System Model framework.

Stafford Beer within the science of cybernetics which concerns itself how organizations maintain their identity, and fulfil their purpose within their environment.

Viable means capable of independent existence and implies both maintaining internal stability and adaptation to a changing environment. “Internal stability” and “adaptation” can be in conflict, particularly if the relevant environment is changing rapidly, so the viable system model (VSM) **is about maintaining a balance** between the two such that the system is able to survive.

The VSM is a model of the structures and functions that are both necessary and sufficient for the long term survival of a system in a changing environment. Allenna Leonard, Beer’s longtime partner, suggested that the most useful way to think about the VSM is as a language. The VSM is a language of viability. The VSM is a language for diagnosing organizations and managerial teams in terms of their viability or lack thereof. The VSM is also a language for designing organizations and **managerial teams that will be viable**.

According to Beer the following characteristics are essential for any social, economic , industrial management system to ensure viability:

- **The ability to grow** (maximize potential).
- **The ability to renew.**
- **Ability to ensure robustness** against internal breakdown and error.
- **Ability to continuously adapt** in a changing environment and ability to survive under unexpected conditions.
- **The ability to learn** from repeated experience and ensure optimum response to the stimuli.
- **The ability to maintain systemic equilibrium** via multi communication connections with the environment.

The Viable System Model (VSM) of Beer is an approach of Organizational Cybernetics that aims at the design and diagnosis of complex organization. By applying this approach weakness of structure, function, communication and interaction can be easily revealed and adaptation initiatives realized to maintain viability. According to VSM organizational system shall have **normative**, **strategic**, **auditing**, **coordinating**. **Operative** management and alarming functions that operate and interact in order to maintain organizational viability.

Beer defines Cybernetics as the science of effective organization and treats not things but ways of behaving. The role of Management Cybernetics is to help the management (command and control) understand:

- How the system (organization) works or does not work.
- Why it works in a specific way.
- What to do about the system (organization) to influence the outcome in a way which is beneficial to the purpose being served.

Organization cybernetics based on VSM model whereby ‘a good regulator of a system must be a model of the system which should possess a degree of variety or complexity in accordance with the system they trying to govern. This implies having necessary conditions for the system to be viable by means of key governance functions;

Implementation

Primary activities, those responsible for producing the products or services towards the environment implied by the organization’s identity defined by **normative management to ensure that it maximizes its value proposition.**

Co-ordination

A viable system also has systems in place to co-ordinate the interfaces of its value-adding functions and the operations of its primary sub-units. In other words, co-ordination is necessary between the value-adding functions as well as between the embedded primary activities in order to optimize and achieve synergy, optimization and synchronization in order to maximize system **potentiality and capability**.

Control

This is the channel from operational management through which resources are negotiated, direct line management instructions and goals are issued and accountability reports flow upwards to keep the meta-level management in touch with events. The control function needs an assurance that the accountability reports it **receives** are indeed an accurate reflection of the status of primary activities by means of its **validation** services.

Intelligence

The Intelligence function management by the **strategic management service** is the two-way link between the primary activity and its external environment. Intelligence is fundamental to adaptability; provides the primary activity with continuous feedback on marketplace conditions, technology changes and all external factors that are likely to be relevant to it in the future; secondly, it projects the identity and message of the organization into its environment. The intelligence function is strongly future focused. It is concerned with planning the way ahead in the light of external environmental changes and internal organizational capabilities so that the organization can invent its own future (as opposed to being controlled by the environment), create new industry paradigm, elevate its potential, provide operations management guidance with respect to adaptation.

Policy

Policy making function managed by the **normative management service** provides closure to the system as a whole. The main roles of Policy are to provide clarity about the overall direction, values and purpose of the organizational unit; and to design, at the highest level, the conditions for **organizational effectiveness**.

From Systemic Governance perceptive the system architecture blueprint shall consist of a governance model based on Viable System Model (VSM) framework which will used for governance efficacy and diagnosis associated to a system cockpit to enable that enable effective adaptation, viability, resilience and **leverages potential**.

Viable System Model (VSM)

Viability is the capacity of a system (organization, state, company, controlling body etc...) to maintain a separate existence and survive via adaptation over time in spite of changes in the environment where its identity will persist through process of learning, adaption and evolution.

The **Viable System Model (VSM)** is a model of the organisational structure of any autonomous system capable of producing itself. A viable system is any system organised in such a way as to meet the demands of surviving in the changing environment. One of the prime features of systems that survive is that they are adaptable. The VSM expresses a model for a viable system, which is an abstracted Management Cybernetic (regulation theory) description that is applicable to any organisation that is a viable system and capable of autonomy.

In a ‘viable system’ the system and subsystem has following behaviour:

- Has a purpose.
- Realizes its tasks.
- It senses its internal and external environment.
- It coordinate its activities with other systems.

- Maintains a repository of past with respect to key variables.
- It plans its activities based on its strategy.
- It adapts to changes to its environment.

The model was developed by operations research theorist and cybernetician Stafford Beer in his book Brain of the Firm (1972). Together with Beer's earlier works on cybernetics applied to management, this book effectively founded management cybernetics.

The first thing to note about the cybernetic theory of organizations encapsulated in the VSM is that viable systems are recursive; viable systems contain viable systems that can be modelled using an identical cybernetic description as the higher (and lower) level systems in the containment hierarchy (Beer expresses this property of viable systems as **cybernetic isomorphism**[19]).

Components of the viable system model

VSM amplifies the science of control in order to have necessary and sufficient conditions for any system to be viable. VSM is based on 5 systems which undertake a systemic role to manage complex systems in order to achieve homeostatic equilibrium of a system under control.

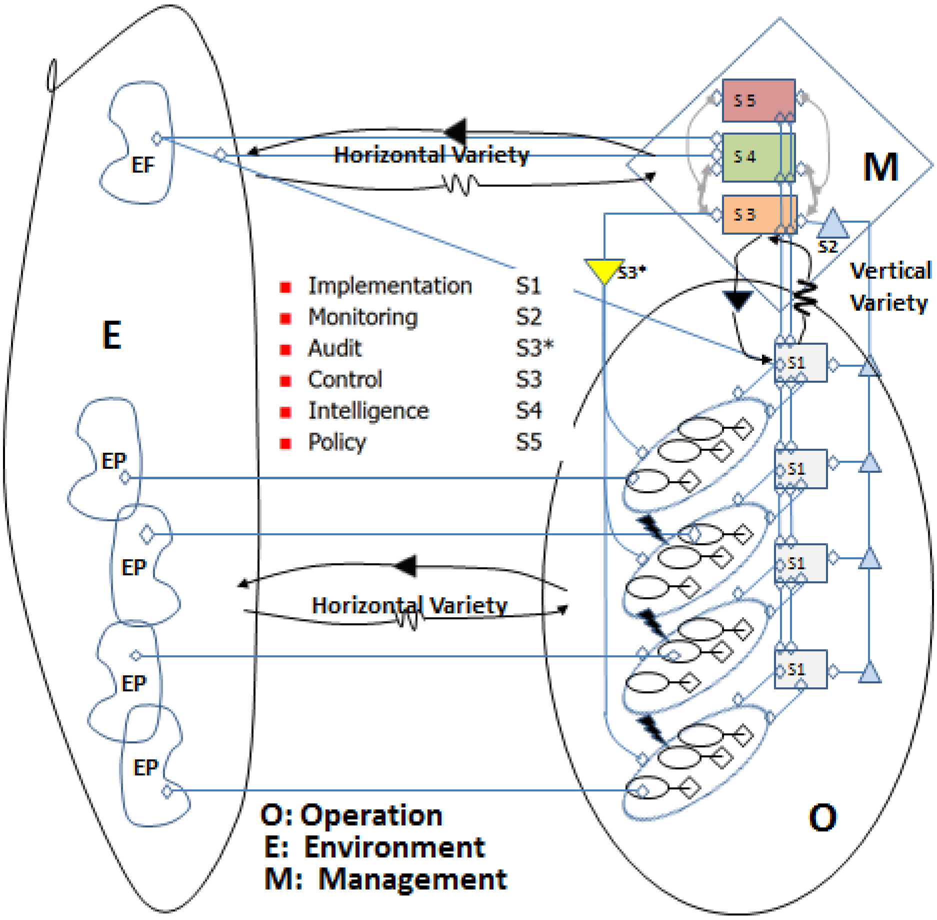
A viable system is composed of five interacting sub-systems which may be mapped onto aspects of organizational structure. In broad terms Systems 1–3 are concerned with the 'here and now' (Operational Management) of the organization's operations, System 4 is concerned with the 'there and then' (Strategic Management) – strategical responses to the effects of external, environmental and future demands on the organization. **System 5 is concerned with balancing the 'here and now' and the 'there and then' to give policy directives which maintain the organization as a viable entity** (Normative Management).

- **System 1** in a viable system contains several primary activities responsible for delivery of services and products. Each System 1 primary activity is itself a viable system due to the recursive nature of systems as described above. These are concerned with performing a function that implements at least part of the key transformation of the organization purpose.

---

[19] (A) A mapping of one entity into another having the same elemental structure, whereby the behaviors of the two entities are identically describable. (John Warfield). (B) A formal correspondence of general principles or even of special laws. (Bertalanffy) (C) A set of principles may be transferred from one field to another without need to duplicate the effort. (Weinberg) (D) A one-to-one correspondence between the elements of two sets such that the result of an operation on elements of one set corresponds to the result of the analogous operation on their images in the other set.

- **System 2** represents the information channels and bodies that allow the primary activities in System 1 to communicate between each other and which allow System 3 to monitor and co-ordinate the activities within System 1. Represents the scheduling function of shared resources to be used by System 1, resolution of conflict between System 1.
- **System 3** represents the structures and controls that are put into place to establish the rules, resources, rights and responsibilities of System 1 and to provide an interface with Systems 4/5. Represents the big picture view of the processes inside of System 1, provides goals, expects accountability from System 1 performance (capability, potentiality, efficiency), resource bargaining.
- **System 3*** main function to obtain how System 1 is working ensuring between S1 and S3 is complete, information that does not get to System 3 (accountability) via normal channel: basically audit function (quality audits, work studies , special surveys).
- **System 4** – The bodies that make up System 4 are responsible for looking outwards to the environmental scanning, strategy, planning and innovation and to monitor how the organization needs to adapt to remain viable.
- **System 5** is responsible for policy, identity, ultimate authority decisions within the organization as a whole to balance demands from different parts of the organization and steer the organization as a whole.



In addition to the subsystems that make up the first level of recursion, the environment is represented in the model. The presence of the environment in the model is necessary as the domain of action of the system and without it there is no way in the model to contextualize or ground the internal interactions of the organization.

Furthermore the VSM model contains fundamental aspects around algedonic critical for resilience and provides a critical baseline for adaptation.

- **Algedonic alerts** are alarms and rewards that escalate through the levels of recursion when actual performance fails or exceeds capability.
- **Adaptation**
  Interactions between these sub-systems support improved processes and/or self-adaptation to a changing environment:
- **Exception** Management for short-term : System 1 to System 3, System 1 to System 5)
- Corrective action (review of System 3* / exception ↔3 / 4, also driver for Process Improvement)

- Issue tracking / issue-management (usually triggered by exception mgt, System 2 and/or System 3)
- Process improvement (interaction up and down between any System 1..↔..System 5)

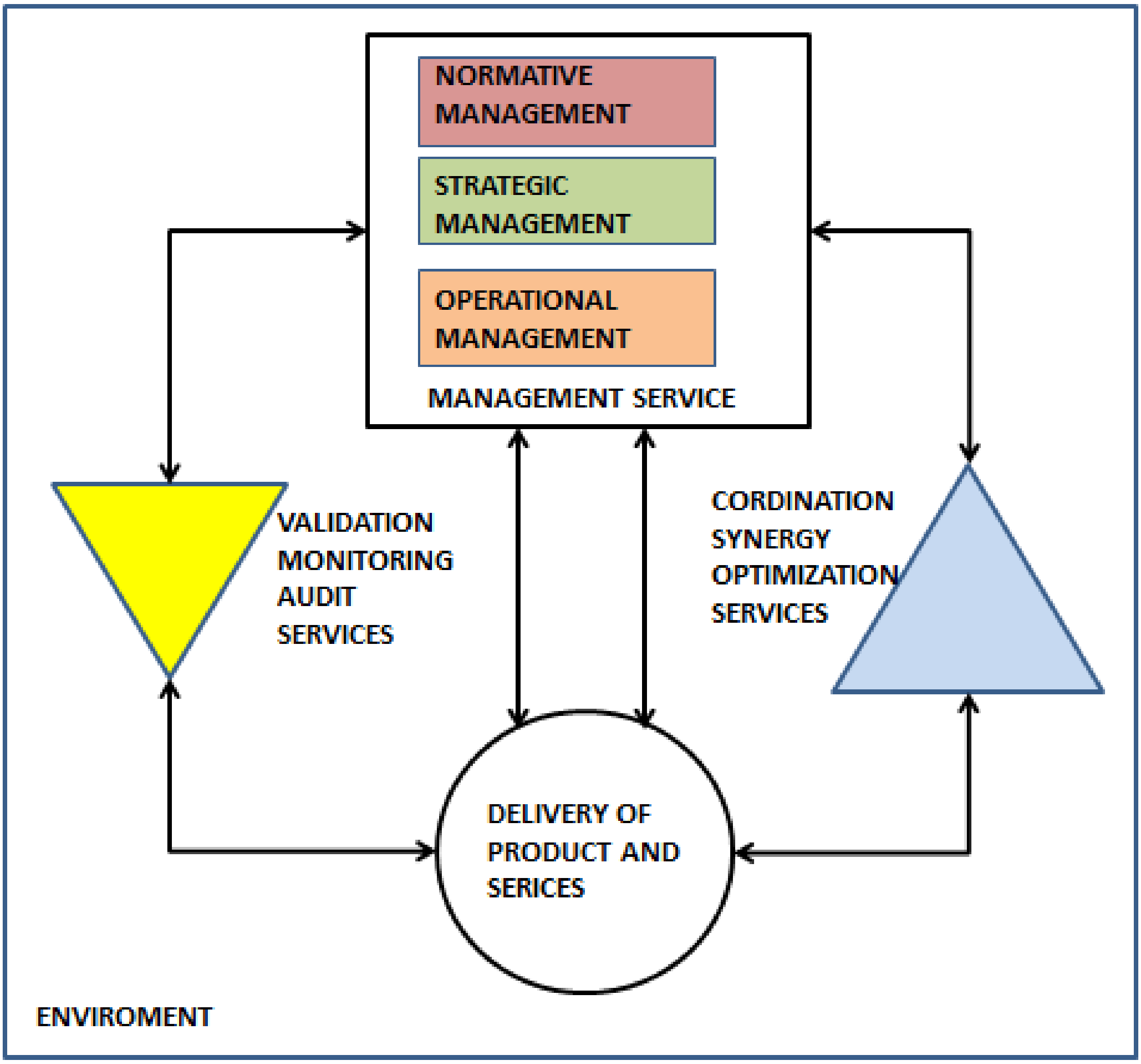
Key relationship with VSM

The Viable System model forms the cornerstone for Systemic Context with respect to organization design and continuous diagnosis in a changing environment. Further VSM has critical interrelationship with the following areas:

- **System definitions** and its **variables**.
- **Panarchy**: in achieving high level of potential, connectedness (Context) and resilience (algedonic channels) are to design the organization and carry-out continuous diagnosis in a changing environment.
- **System Content**: with respect to system interaction of the elements in order to maximize capability, potentiality, efficiency and profitability. System Content also feeds VSM with ‘to-de’ organizational requirements that will drive System 3, 2 and 1.
- **Systemic process**: with respect to supporting processes, events , function , supporting systems an organizational units.
- **Systemic Enterprise Architecture**: driver to define EA strategy, goals, objects business processes to support the strategy which eventually drive supporting IT application systems.

Normative management

From a context (**Management Cybernetic**) perspective, the purpose of Normative Management is the effective definition of management functions and ensure the efficacy of these functions considering changing environmental conditions in order to sustain **viability**.


NORMATIVE MANAGEMENT
STRATEGIC MANAGEMENT
OPERATIONAL MANAGEMENT
MANAGEMENT SERVICE
VALIDATION MONITORING AUDIT SERVICES
CORDINATION SYNERGY OPTIMIZATION SERVICES
DELIVERY OF PRODUCT AND SERICES
ENVIROMENT

Normative management functions:

- Defines the organization’s overall vision, mission and strategy
- Establishes its ground rules.
- It defines the organization’s strategic direction from those recommended to it by strategic management.
- Develops policies
- Develop strategic goals,
- Provides the means of enforcing the rules, changes organizational structure as required, and monitors the tension between the demands of current operations (operational

management) and future preparedness (strategic management), and determines when and how to shift the balance from one to the other

Normative Management Function Efficacy:

With respect to Transformation Analysis key objective is to ensure that functions are in place and to determine the efficacy of these functions keeping in consideration **potential**, **resilience** and **viability**.

Strategic management

From a context **MC** (Management Cybernetic) perspective, Strategic Management is future oriented and externally focused. Strategic management with respect to **MC** (**VSM** system 4) adopts an "outside and then" perspective that looks at the bigger picture and longer term.

- It is the intelligence gathering function.
- It collects and analyses information about changing conditions from internal and external sources and assesses its impact on organizational strategy.
- It identifies opportunities and threats and ensures that the system can survive in a changing environment; it uses benchmarks to assess organizational performance relative to competitors; and it develops strategic options.
- Strategic management acts as an information clearing house for operational units. It has been described as "an interactive assemblage of managers" (from Beer, reported in Jackson, (1991)) evoking images of intensive management debate and discussion. The strategic management function receives and aggregates information from multiple operational units and redistributes it back to them when immediate action is required.
- Strategic management also liaises between operational and normative management. It shields the normative function from information irrelevant to major strategic decisions by filtering and aggregating information received from operational management (Jackson, 1991). Simons (2000) interactive controls contribute to the strategic management function.

Operation management

Operations management is chiefly concerned with planning, organizing and supervising in the contexts of production, manufacturing or the provision of services. As such, it is delivery-focused, ensuring that an organization successfully turns inputs to outputs in an efficient manner. The inputs themselves could represent anything from materials, equipment and technology to human resources such as staff or workers.

From a Organizational Cybernetics or VSM perspective Operation Management focus is on ‘here’ and ‘now’ (short term operative space) with it’s main focus:

- For allocating resources to support the day to day work of the organization (system 1).
- Prescribing routines, policies and standard operating procedures.
- To minimize friction between operational units and to coordinate their activities (system 2)
- Creating roles, processes and procedures to develop synergy and promote efficiency over and above that which is possible by an individual operating unit acting on its own.
- Monitoring and auditing information supplied by the operational units and investigating.
- deviations from expected performance targets.
- Operational units within System 1 are producing and supplying the market with products and services that it supposed to deliver Operational.
- Addresses the efficient execution, coordination and control of the operational (or primary) activities performed in the group of operational units.
- Optimize the usage of various System 1 resource in order to delivery products and services ensuring ideal throughput by achieving highest level of efficiency and efficacy.
- Optimize the functioning of the ‘whole’ composed of different operational units.
- Internal stability of the various System 1 units.
- Defining operational goals.
- Guaranteeing cohesion with respect to mission and identity.

Purpose mission vision

According to cybernetician, the purpose of a system is what it does or what it make does what it perform less the intelligence in.

The purpose of a system can be read from the intentions of those (governors) who **design**, operate, or promote it. From a cybernetic perspective **complex systems** are not controllable by simple notions of management, and interventions in a system can best be understood by looking at how they affect observed system behavior.

All systems seek to achieve a purpose. Whether human made or natural, **all systems strive to do something**. When creating a new system or **modifying an existing one**, it is done in order that the resultant system does something "**useful**".

It is also possible that the system may have more than one purpose specifically evolved system. Automobile manufacturer not only has defined purpose for the automobile manufacturing system but may own a bank to assist customer with finance or even insurance company. The bank from the viewpoint automobile manufacturing system is considered as a sub-system and the banks purpose is a sub-purpose of the main system. From a view of the bank system, the purpose encompasses the sub-process and other purpose. Therefore the achievement of system purpose is also dependent on achievement of lower level purpose and so on.

Determining effective purpose of the system is fundamental to long term viability of a system and governs related mission, vision and adaptation (change, innovation, transformation) strategies. From a governance perspective system purpose must be constantly reviewed to determine its efficacy in achieving 'what it does' .

Vision: An aspirational description of what an organization would like to achieve or accomplish in the mid-term or long-term future. It is intended to serves as a clear guide for choosing current and future courses of action.

Mission: A mission statement, a type of statement of purpose, is a statement which is used to communicate the purpose of an organization.

A mission statement is intended to clarify the '**what**' and '**who**' of a company, while a vision statement adds the '**why**' and '**how**'.

Systemic governance not only addresses vision coherence by the system various operational entities, it also addresses its efficacy; the ideal system mission and vision considering:

- Current system state.
- Environmental condition (changing environmental conditions).
- System adaptive status, its adaptive cycle with respect properties of sustainability state elements: potential, resilience and connectedness.

Systemic and system performance

About system performance

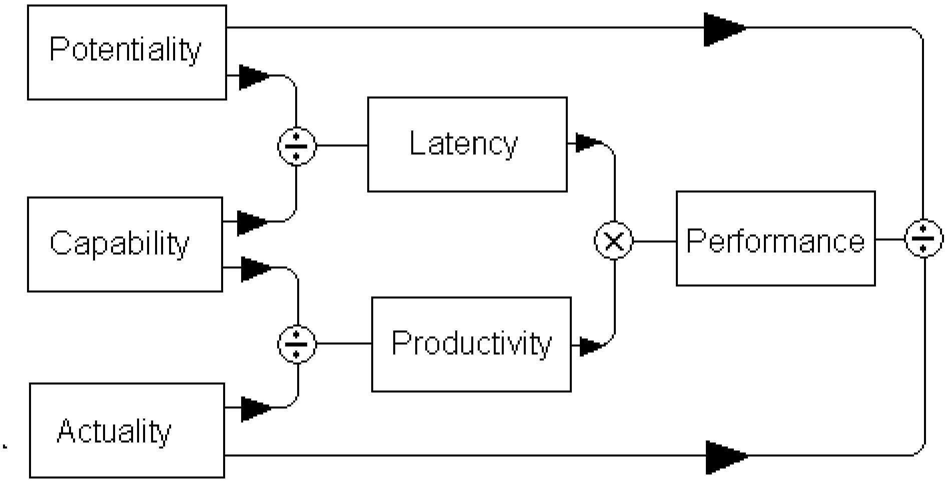
> **“A system is a set of elements or parts that is coherently organized and interconnected in a pattern or structure that produces a characteristic set of behaviors, often classified as its function or purpose.”** (Donella Meadows)

A system consists of interconnected set of elements (sub-systems) that are coherently organized and work in coordination with each other to achieve a desired goal or overall objectives of the whole. These elements derive their strength by means of association and influence with other elements whereby **collective contribution of the system is greater aggregate individual elements: this is known as systemic synergy**. A system at any point in time consists of 3 critical interrelated elements where their properties determine system performance.

The **performance of the system** depends on **how well the parts fit** together, not how well they perform individually and the ‘whole’ system exhibits emergent properties that are not to be found in its parts.

It is important to distinguish between Systemic Performance and System Performance. Systemic Performance is based on the possible system potential as dictated by its system purpose and mission of what is possible excluding internal constraints and capabilities. Potential sets the limits to what is possible within the known environment.

- **System performance is the possible performance** of the established system based on its capabilities, processes and supports systems (resources such as factories machines) towards its stated environment entities.
- From a governance efficacy perspective of the defined system, the key focus with respect to operational units is to measure:
- Systemic performance: is based ratio between actuality (actual performance) and systemic potential.
- **System performance is the based ratio** between **actuality** (actual performance) and **potentiality** of defined system (defined capability, process and support systems). The key governance objective is to maximize performance by focusing on initiatives that **maximize potentiality**.
- **Productivity**: is the ratio of actuality and capability.
- **Latency**: is the ratio of capability and potentiality.



The variables associated with the above also provide a key indication with respect to adaption, innovation and transformation; furthermore it provides clear indication in the efficacy of IT sub-system in coordinating effectively the operational units.

Potentiality: This is what system should be doing within the boundaries of existing system state (same function, structure, identity, and feedback's) by developing its existing resources and removing constraints or elevating constraints to **maximize throughput**, improvements to management control (context) and processes although still operating within the bounds of what is already known to be feasible.

Capability: This is what system should be doing (still right now) with existing resources, under existing constraints, if there is management focus to eliminate waste, increase output resulting in improvements in productivity and efficiency.

Actuality: present way of managing the system, with existing resources, under existing constraints and exiting governance framework

Profitability is the ability of a business to earn a profit. A profit is what is left of the revenue a business generates after it pays all expenses directly related to the generation of the revenue, such as producing a product, and other expenses related to the conduct of the business activities.

Efficiency is the (often measurable) ability to avoid wasting materials, energy, efforts, money, and time in doing something or in producing a desired result. In a more general sense, it is the ability to do things well, successfully, and without waste. In more mathematical or scientific terms, it is a measure of the extent to which input is well used for an intended task or function (output). It often specifically comprises the capability of a specific application of effort to produce a specific outcome with a minimum amount or quantity of waste, expense, or unnecessary effort. Efficiency of course refers to very different inputs and outputs in different fields and industries.

Effectiveness and **efficiency** are attained through interaction of of the sub-systems in pursuit of the **purpose** of the system in its environment. The goal of sub-systems is concerned with the purpose of the system and the means of achieving that purpose:

- The human sub-system deals with the people and their management and motivation
- The technical sub-system handles the operations (input-transformation-output) with the aid of human sub-system
- Managerial sub-system co-ordinates and manages each of the others balancing their relationship and attending to environmental relationship to ensure viability.

Being **effective** is about doing the right things, while being **efficient** is about doing things right are both fundamental in achieving goals related to potential, potentiality and capability. This is only possible if there is total cohesion by all the sub-systems with respect pursuit of system purpose.

System throughput

Throughput rather than output plays an fundamental role system performance.

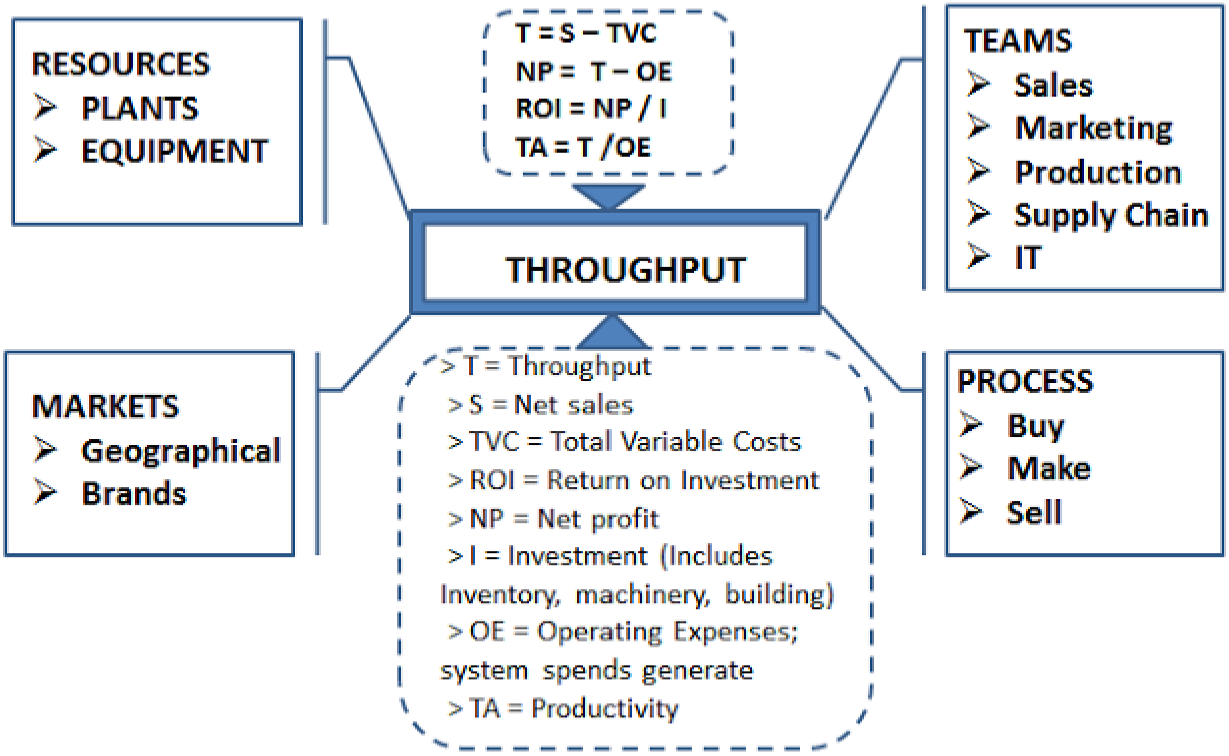
The key difference is that throughput is based on what is actually billed and delivered, while output is something produced and sitting in inventory providing zero value to the organization. Fundamentally throughput relates to cash flow, productivity and profitability; the key elements of any success factor of an organization.

Generally most KPI are a waste of time and effort. Most are ‘so what’ KPI. They are isolated KPI that do not contribute to real business benefits. Some are mainly output related rather than throughput related; Example case is inventory versus throughput.

Having throughput as a KPI measure provides the ability for any organization to achieve its goal; the goal of being profitable and ability to grow. The rest have no relevance.

Throughput also directly influence productivity, net-profit; all those fundamental elements that are critical to any organization but strangely never really measured correctly.

Measuring throughput on its own provides limited value without linkages to the organizational elements resources, markets, teams and process which are all part of the system. Throughput is the outcome of a system. System Thinking considerations:



- A system is greater than the sum of its parts.
- A system is not the sum of its elements/parts – its performance depends on the efficacy system element interactions. IT on its own is a sub-systems which interacts with other producing elements sub-systems (Procurement, production, quality ..) . In order to maximize manufacturing, the objective is not output but rather throughput (what is made and sold). The parts that interact can be the following:
  - Manufacturing Resources, Tooling.
  - Skilled resources.
  - Manufacturing execution system.
  - Manufacturing planning and control system.
  - Management structure.
  - Policies.

The performance of the system depends on how well the parts fit together and how constraints effectively managed.

Therefore, to maximize throughput it is important to optimize the interaction between the various elements of the system.

Introducing multi-dimensional throughput KPI measurement will ensure the visibility of direct contribution of related elements that have an impact on throughput:

- **Resources**
  - Manufacturing Plants
  - Throughput for actual manufacturing site
  - Productivity for actual manufacturing site
  - Manufacturing equipment / System
  - Throughput for actual key constraining resources
- **Markets**
  - Geographical area
  - Product Brands
  - Customer groups
  - Organizational Teams
- **Sales**
  - Marketing
- **Information Technology [IT]**
  - Manufacturing
  - Supply Chain
  - Finance
- **Processes**
  - Design
  - Order
  - Make
  - Sell
- Business Transformation projects sometimes fail because apart from change management there is no clear indication how transformation contributes to real benefits; how will it contribute to increasing throughput. Concepts:

[T] Throughput is the rate at which the system produces “goal units.” When the goal units are money (in for-profit businesses), throughput is net sales (S) less totally variable cost (TVC), generally the cost of the raw materials (T = S – TVC). Note that T only exists when there is a sale of the product or service. Producing materials that sit in a warehouse does not form part of throughput but rather investment. (“Throughput” is sometimes referred to as “throughput contribution” and has similarities to the concept of “contribution” in marginal costing which is sales revenues less “variable” costs – “variable” being defined according to the marginal costing philosophy.)

[I] Investment is the money tied up in the system. This is money associated with inventory, machinery, buildings, and other assets and liabilities. In earlier Theory of Constraints (TOC) documentation, the “I” was interchanged between “inventory” and “investment.” The preferred term is now only “investment.” Note that TOC recommends inventory be valued strictly on totally variable cost associated with creating the inventory, not with additional cost allocations from overhead.

[OE] Operating expense is the money the system spends in generating “goal units.” For physical products, OE is all expenses except the cost of the raw materials. OE includes maintenance, utilities, rent, taxes and payroll.

Organizations that wish to increase their profitability should consider the following:

- Increase throughput? How to increase, and in what areas?
- Reduce investment (inventory) (money that cannot be used)? How?
- Reduce operating expense? How?

The answers to these questions will determine the impact of proposed changes on system wide measurements:

1. **[NP] Net Profit** = Throughput – Operating Expense **= [T] - [OE]**
2. **[ROI] Return On Investment** = Net Profit / Investment **= [NP] / [I]**
3. **[TA] Productivity** = Throughput / Operating Expense **= [T] / [OE]**
4. **[IT] Investment Turns** = Throughput / Investment **= [T] / [I]**

About systems

Introduction

“A system is a set of elements or parts that is coherently organized and inter-connected in a pattern or structure that produces a characteristic set of behaviors, often classified as its function or purpose.” (Donella Meadows)

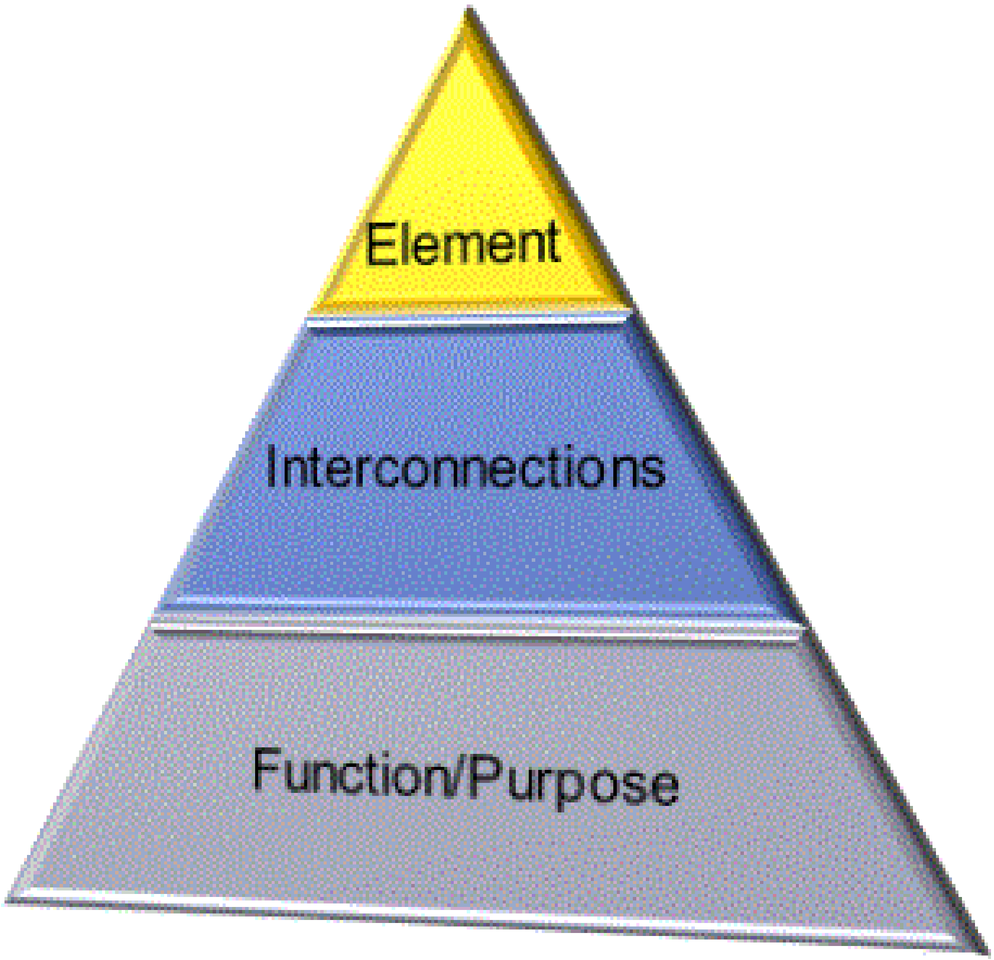
The ‘whole’ system exhibits emergent properties that are not to be found in its parts each part has properties not possessed by the whole.

The behavior of a system cannot be known just by knowing the elements of which the system is made.

A system must consist of the following:

- **Function** or purpose. Function is used for a nonhuman system, and purpose for a human one. Many systems have both human and non-human elements. Purposes are deduced from behavior, not from rhetoric or stated goals.
- **Elements** : structure define by parts and compositions.
- **Behavior** which involves inputs, processing of outputs of materials, energy or information.
- **Interconnection**: parts have functional and structural relationship between each other, relationships hold the elements together. Many of the interconnections in systems operate through the flow of information. Information holds systems together and plays a great role in how they operate.
- **Systems within systems**

The elements are the parts of the system we are most likely to notice. They are least important in defining the unique characteristics of the system.leverage1 Changing elements has the least effect n the system. If interconnections change, the system may be greatly altered. Function/purpose is the least obvious part of the system. It is the most crucial determinant of the system’s behavior. Changes in function or purpose can be drastic / profound.



In order to undertake effective Systemic Transformation that has intended realization objectives, it important to undertake analysis related to complex systems:

- **System definition:** elements, purpose, its variables and related attributes.
- **Systemic potential:** potentiality and capability.
- **Resilience management**: the capacity of a system to tolerate disturbances
- **Variety engineering**: variety implies the number of distinguishable number of states of a system while variety engineering is about control and regulation reduction of variety: perturbations with high variety affect the system's internal state (stability criteria), which should be kept as close as possible to the goal state, and therefore exhibit a low variety. So in a sense control prevents the transmission of variety from environment to system.
- **Adaptability: t**he ability of a system (e.g. company/organization/state) to adapt itself efficiently and rapidly to changed circumstances. An adaptive system is therefore an

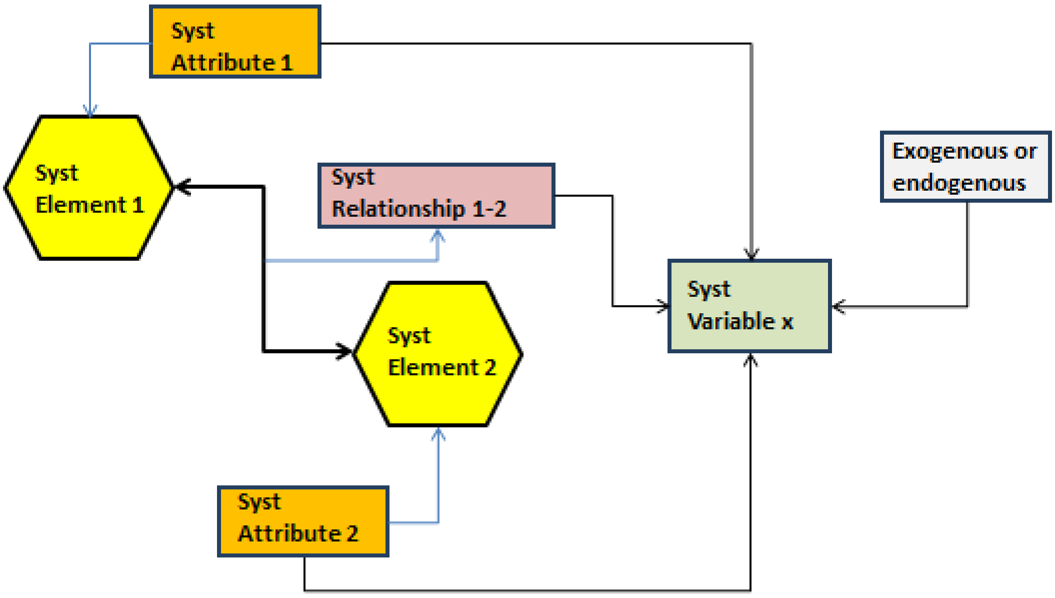
open system that is able to fit its behavior according to changes in its environment or in parts of the system itself

- Performance of the system depends on how well the parts fit together, not how well they perform individually. A system being a whole cannot be leveraged but rather places within the system need to leveraged in order to create changes.
- A constraint is a limitation, imposed by outside circumstances or by system behavior (ourselves) , that materially affects our ability to do something and limits a person or an organization in achieving their goal. Constraints directly impact systemic capability and potentiality.

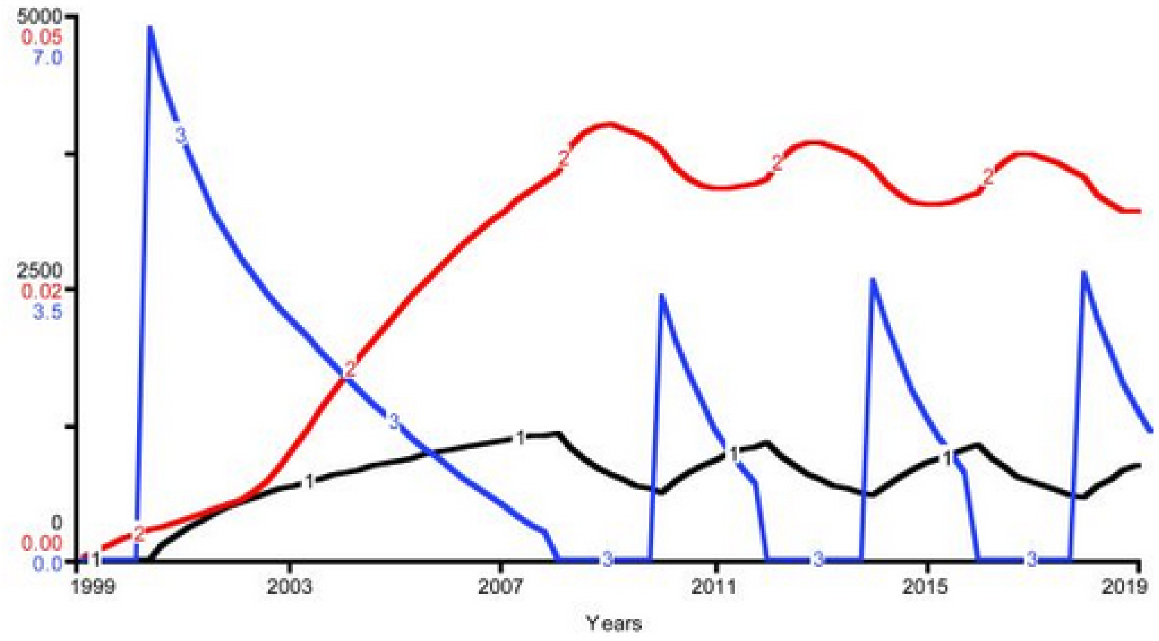
System behavior

[SC] System content is what is contained in a system which describes function or purpose.

A system is a group of interacting, interrelated, and interdependent components that form a complex and unified whole. System Dynamics (SD) is a framework for understating how elements within the system interact.



From a content perspective a system is a group of interacting, interrelated, and interdependent elements that form a complex and unified whole that have purpose or function whereby the state of the system is the set of values held by its variables at any given time. System Dynamic provides a high level view of the system emphasizing the interactions between its constituent parts, as well as the impact of time on its dynamic behavior.



Systemic Content is about understanding **dominant influences** (positive and negative) that determine conditions of system elements. Objective of System Dynamics is to define mental models is to determine **ideal system state**.

Key considerations within Systemic Behaviour:

- System dynamics focuses on the structure and behavior of systems composed of interacting feedback loops. The dynamics arise from the interaction of two types of feedback loops, positive and negative loops. Positive loops tend to reinforce or amplify whatever is happening in the system. Negative loops counteract and oppose change.
- System Dynamics helps in designing the interconnections and structures to give more confidence and predictability in behavior of the systems. Its focus on the structure and behavior of systems composed of interacting feedback loops.
- System dynamics is an approach to understanding the behavior of complex systems over time. It deals with internal feedback loops and time delays that affect the behavior of the entire system. Simulation with SD models is used for learning about the dynamic complexity of systems, identification of optimal policies in existing systems, improvement of system behavior through parameter or structural changes.
- Critical Aspects within the Systemic Content domain:
    - Thinking in terms of cause-and-effect relationships.
    - Focusing on the feedback linkages among components of a system.

  - Determining the appropriate boundaries for defining what is to be included within a system.
  - Causal thinking is the key to organizing ideas in a system dynamics study.

System dynamics

About system dynamics

[SD] System dynamics is an approach to understanding the non-linear behavior of complex systems over time using stocks, flows, **internal feedback loops**, and time delays.

System dynamics is a methodology and mathematical modelling technique to frame, understand, and **discuss complex issues and problems**.

System Dynamics key considerations:

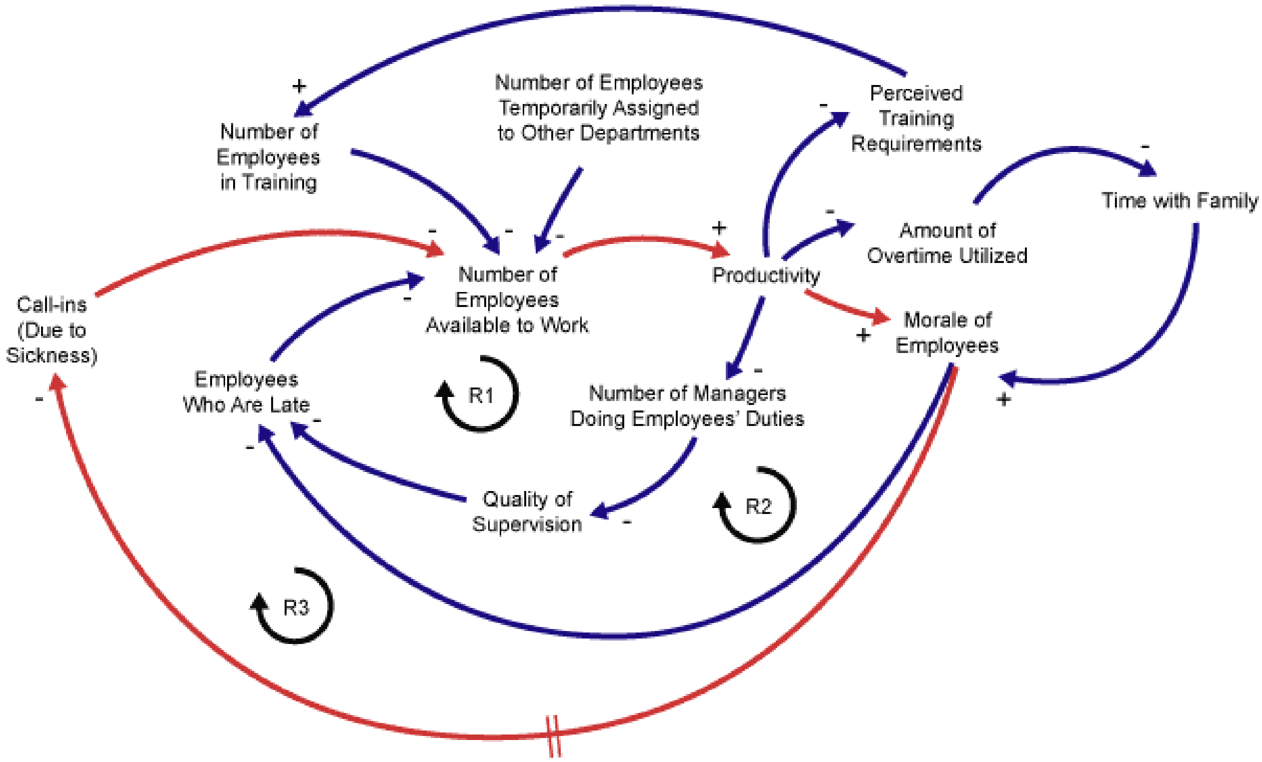
- System – a group of independent but interrelated elements comprising an integrated whole.
- Systems thinking – the process of understanding how system elements interact to produce system behavior.

The systems are characterized by:

- Structure – composition of elements.
- Behavior – involved inputs, processes and outputs of material, energy and/or information.
- Interconnections – structural and functional relations between elements.
- Emerging properties - system properties that do not appear in individual elements (e.g. car individual parts cannot move by themselves).

Emergent properties is that it's the property of the **whole, and only exists as a whole**, not a property of the component bits. Emerging properties have a fundamental impact on the system performance. Each organization will have unique emergent properties . emergent phenomena are **best understood by observing a 'pattern resulting from the interactions' among multiple elements in a system** including aspects of the environment.

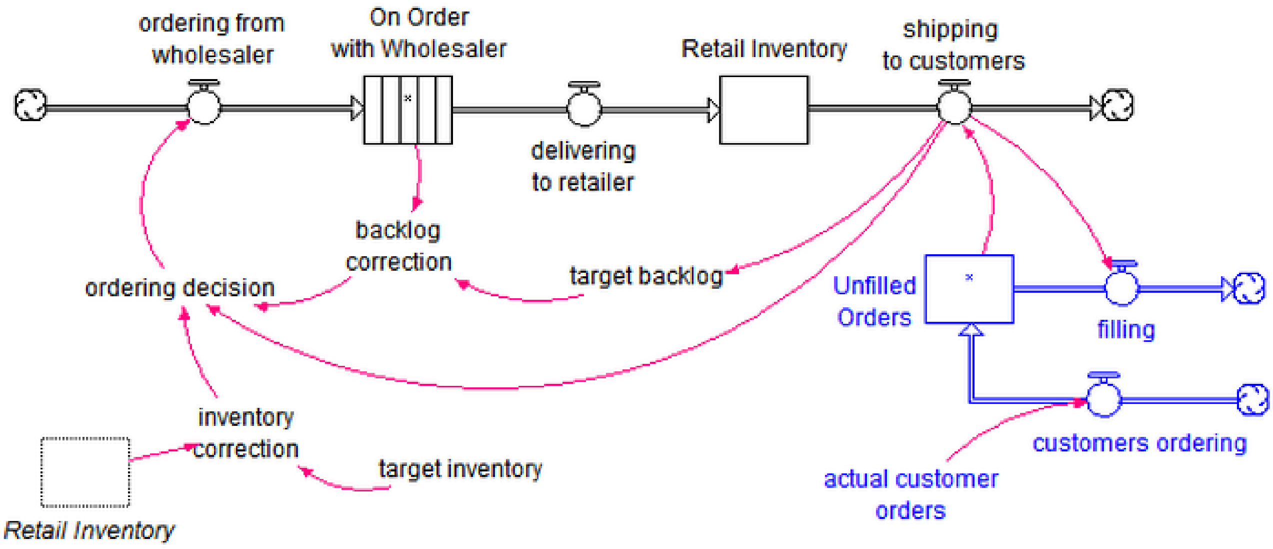
In the System Dynamics methodology, a problem or a system (e.g., ecosystem, political system or mechanical system) is first represented as a **Causal Loop Diagram**.


Number of Employees Temporarily Assigned to Other Departments
Perceived Training Requirements
Number of Employees in Training
Time with Family
Amount of Overtime Utilized
Call-ins (Due to Sickness)
Number of Employees Available to Work
Productivity
Morale of Employees
Employees Who Are Late
R1
Number of Managers Doing Employees' Duties
Quality of Supervision
R2
R3
+
-

A causal loop diagram is a simple map of a system with all its constituent components and their interactions. By capturing interactions and consequently the feedback loops (see figure below), a causal loop diagram reveals the structure of a system. By understanding the structure of a system, **it becomes possible** to ascertain a system's behavior over a certain time period.

Stock and flow diagrams

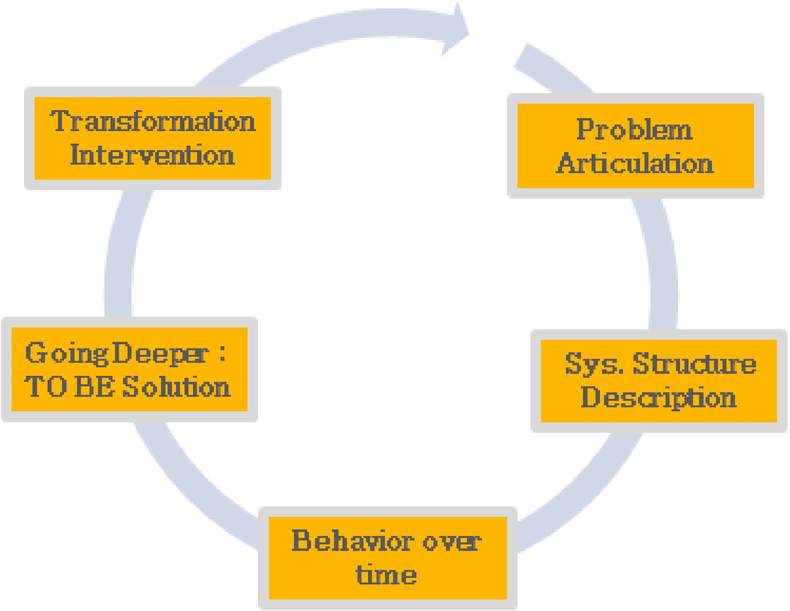
Causal loop diagrams aid in visualizing a system's structure and behavior, and analyzing the system qualitatively over time. To perform a more detailed quantitative analysis, a causal loop diagram is transformed to a stock and flow diagram. A stock and flow model helps in studying and analyzing the system in a quantitative way; such models are usually built and simulated using computer software.



A stock is the term for any entity that accumulates or depletes over time. A flow is the rate of change in a stock.

System dynamics analysis

Within the content framework, understanding system behavior is fundamental in steering towards intended realization benefit that fits adaptation objective. This requires a number of Steps achieve intended benefit with respect to resolving problems, to elevate capability and potentiality, system potential and variety engineering. Intended intervention identity initiative applicable within context environment (governance) and define fundamental requirements relevant for Information Architecture realization / realignment.


Problem Articulation
Sys. Structure Description
Behavior over time
Going Deeper : TO BE Solution
Transformation Intervention

System dynamics steps

1. Problem Articulation

Theme selection: What is the intended purpose? What is the problem? Why is the purpose of this analysis? What is the issue the clients are most concerned with? What problem are they trying to address? What is the real problem, not just the symptom of difficulty?

- Reconfirm system purpose: reconfirm what is the objective.
- What results are expected from the system.
- Compared to the goal: what are the actual results.
- This then clarifies differences between vision / expectation and current reality.
- Intended purpose theme selection of the system dynamics initiative: address specific problem, manage potential, elevate capability and potentially, variety engineering articulation.
- Define intended realization benefit: improve… or reduce…
- Illuminate diverse viewpoints of the multiple stakeholders.
- Create focusing statement; statement to channel energy during modelling process to achieve analysis expectations.

2. Describe the systemic structure

Describe systemic structures that are creating dynamic behavior and its patterns. This is fundamental in understanding systemic feedback and dominant influence.

- Define elements and define sub system in question.
- Define relevant variables and system element association.
- Model system structure and behavior (associated archetype) :
  - Causal Loop diagrams.
  - Stock and flow diagrams and simulation.
- Identify behavior of key variables.
- Associate system archetypes.
- Behavior over time graphs.

3. Behavior over time graphs

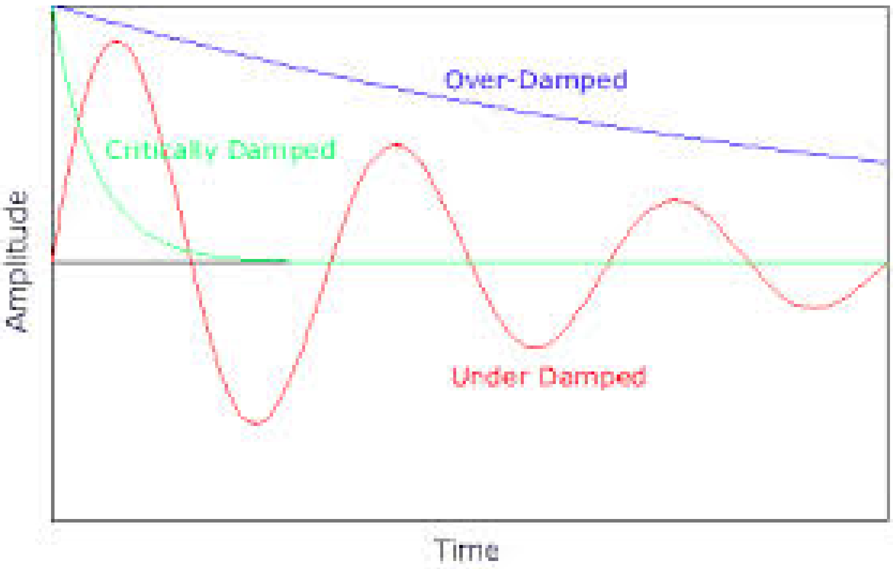
Map behaviour of critical system variables which are part of sub-system understudy in order to connect present to the past associating **events** to patterns of behaviour and emerging properties.

Time horizon: How far in the future should we consider? How far back in the past lie the roots of the problem?

Ensure that graphs have adequate historical data superimposed with critical events.

Clearly plot key variables that exhibit the following:

- Oscillations.

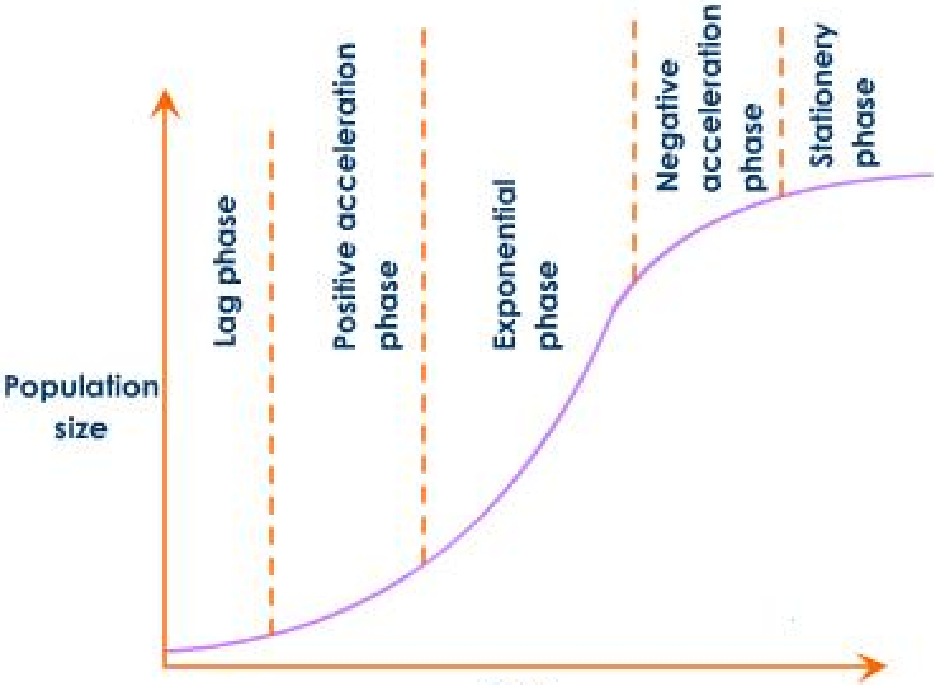


- S shaped growth.
- Runaway growth.
- Flat line, no growth.
- Gradual decline.

4. Going deeper into the analysis

Based on above step system structure and behavior (archetypes) a theory is now possible to define systemic behavior and what is happening (positive and negative aspects). This then requires going deeper in the analysis:

- Revisit purpose of the system (related to larger context) and verify if related subs system are coherent.
- Ask questions:



S-shaped Sigmoid Growth Curve

- Behavior around the problem under-study:
- Is the problem chronic.
- Does it have know pattern of behavior over time.
- How does pattern relate to what is expected to actually occur.

- Historical occurrences of related problems and previous attempts to solve the problem and attempt (what was attempted, by whom, and what outcome) to associate Senge laws of system.
- What is likely to happen if problem in question is not solved ? What are the cost of not changing.
- How would stakeholders see the issue, how the think about the issues and what is important for them.
- How is the issue seen by higher management? What components and factors would they see?
- What other causes are affecting this system? What other effects (unintended) does the system produce.
- Mental models.
- Explore the mental models by using the analysis causal loop models by adding ‘thought bubbles’ that document tendency and direction of information connection, resulting causality, emerging properties and feedback loops (reinforcing and balancing) . This is fundamental in improving the quality of dynamic decisions.
- Association to larger system.
- Add links and loops to connect to larger system in order to enrich the understating effort.
- Clarifying roles.
- Clarify roles, expectation and viewpoint of the different players from the environment and what role they played influencing the system performance.

5. Design solution

Design the solution that will structurally work and achieve intended realization objectives. This implies modelling a ‘to-be’ SD scenario:

- Causal loop diagram clearly showing feedback strength (balancing and feedback).
- Identify if additional elements needed to the loops.
- Weaken the crisis loops.
- System dynamics model and simulations.

- The model must ensure consistency to what is intended, robustness by verifying behavior when stressed to its limits. Verify how the model behaves given uncertainty in parameters, initial conditions, model boundary, and aggregation?

6. Systemic intervention

The intervention must clearly identify the following:

- Policy design:
- Scenario specification: What environmental conditions might arise?
- Policy design: What new decision rules, strategies, and structures might be tried in the real world? How can they be represented in the model?
- What are the effects of the policies?
- How robust are the policy recommendations under different scenarios and given uncertainties?
- Do the policies interact? Are there synergies or compensatory responses?
- Leverage points and related key changes.
- The intended intervention must be associated to systemic transformation initiative that need to be planned and realized (WHAT, WHO, HOW, WHEN, WHERE).
- Clearly define intervention systemic benefit, associated risk and change management impact.
- Identify monitoring criteria with respect to the intervention so as to measure and understand intended efficacy once realized (critical for systemic tower and continuous learning).

Stock and flow modelling

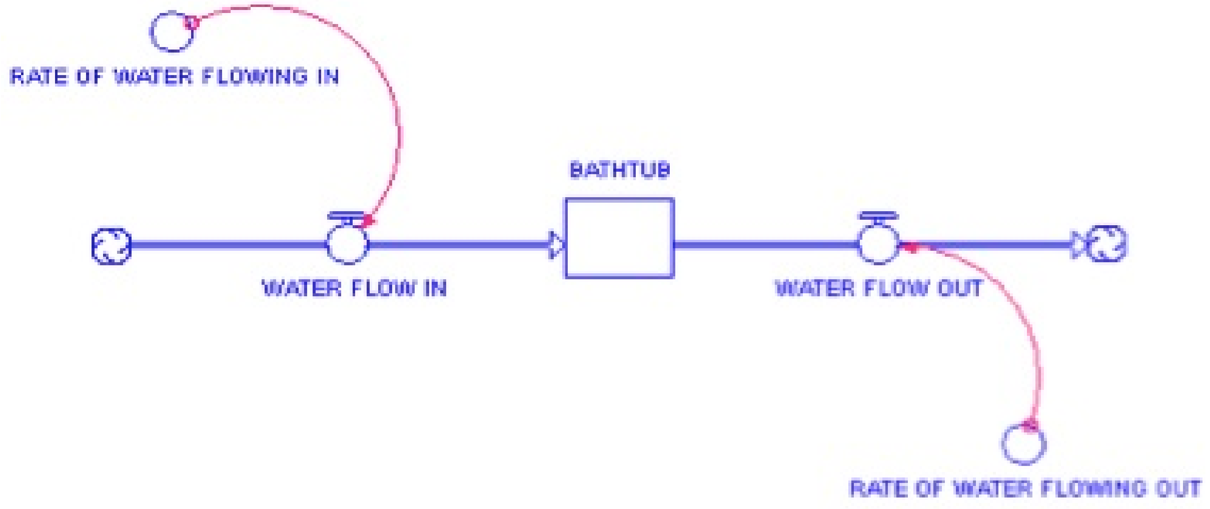
A system is a set of interrelating, interconnected parts or elements that, together, generate some distinct outcome or behavior over time. In dynamical systems modeling, the behavior that the system exhibits over time is called its dynamic.

The causal loop diagrams showed that to go beyond simply analyzing and visualizing the feedback structure of a system, a more powerful technique is needed that included quantitative modelling:

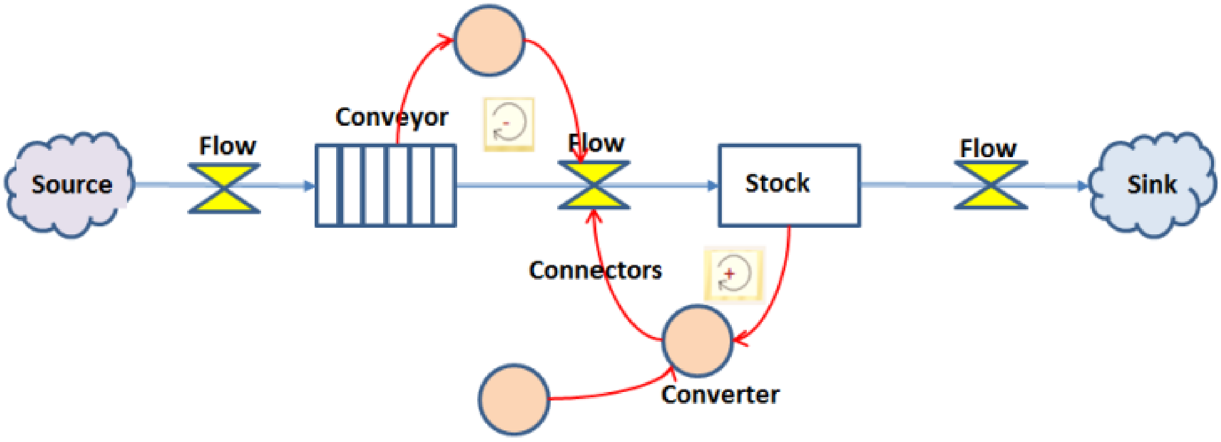
- A technique that visually distinguishes between the parts of the system and what causes them to change.

- A technique that allows for precise – quantitative – specification of all the system's parts and their interrelation.
- A technique that can provide a basis for simulating the behavior of the system over time.
- Technique that enables us to create a business prototype of the system that will allow us to explore its behavior and to test the effect of changes to the system's structure and the policies governing its behavior. Stock and flow diagrams, along with the mathematical expressions that specify each construct, provide such a technique.

To perform a more detailed quantitative analysis, a causal loop diagram is transformed to a stock and flow diagram. A Stock and flow model helps in studying and analyzing the system in a quantitative way.



To perform a more detailed quantitative analysis, a causal loop diagram is transformed to a stock and flow diagram. A Stock and flow model helps in studying and analyzing the system in a quantitative way.



Stock and flow diagrams provide a richer visual language than causal loop diagrams, we distinguish between six main kinds of elements: stocks, flows, converters, connectors, sources and sinks. These elements are explained below and visualized in the following diagram:

STOCK: A stock represent a part of a system whose value at any given instant in time depends on the systems past behaviour. The value of the stocks at a particular instant in time cannot simply be determined by measuring the value of the other parts of the system at that instant in time – the only way you can calculate it is by measuring how it changes at every instant and adding up all these changes.

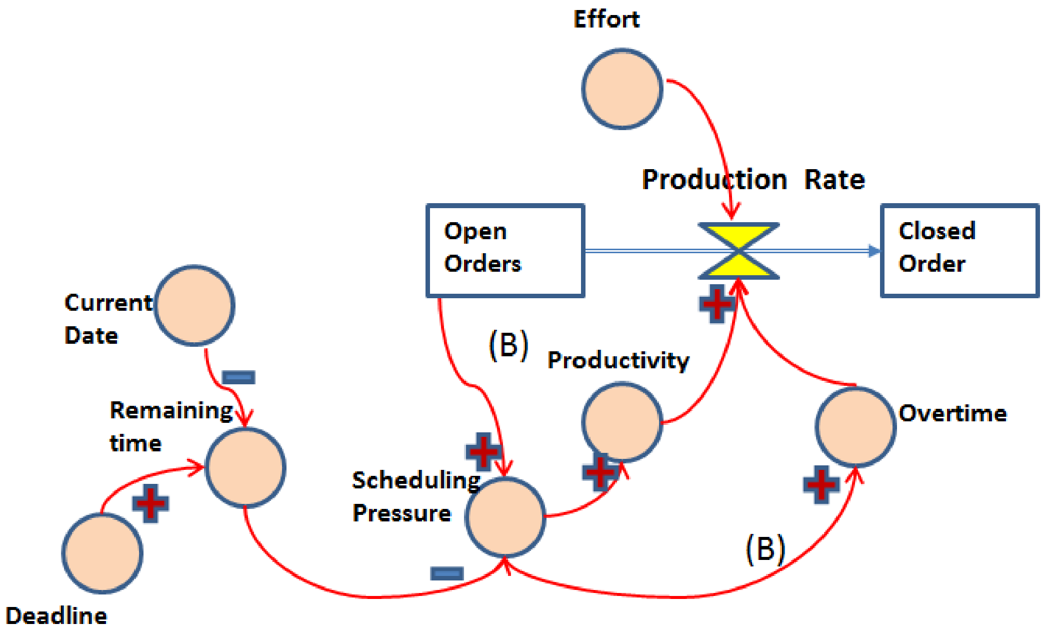
- A stock is a generic symbol for anything that accumulates or drains.
- Stocks are variables that accumulate the effects of other variables.
- “Nouns” that indicate conditions or states of being at a point in time.
- They act as shock absorbers, or buffers, from the changes in the flows.
- They can physical or non-physical: non-physical stocks “states of being” like anger, self-esteem, trust, etc. Importantly, non-physical stocks need not obey the Law of Conservation- they are not zero-su.

FLOWS: Flows represent the rate at which the stock is changing at any given instant, they either flow into a stock (causing it to increase) or flow out of a stock (causing it to decrease).

- A flow is the rate of change of a stock / Variable.
- Flows represent the rate at which the stock is changing at any given instant, they either flow into a stock (causing it to increase) or flow out of a stock (causing it to decrease).
- “Verbs” that represent activities or processes.

CONVERTERS: Converters either represent parts at the boundary of the system (i.e. parts whose value is not determined by the behaviour of the system itself) or they represent parts of a system whose value can be derived from other parts of the system at any time through some computational procedure.

- A converter is used to take input data and manipulate or convert that input into some output signal.

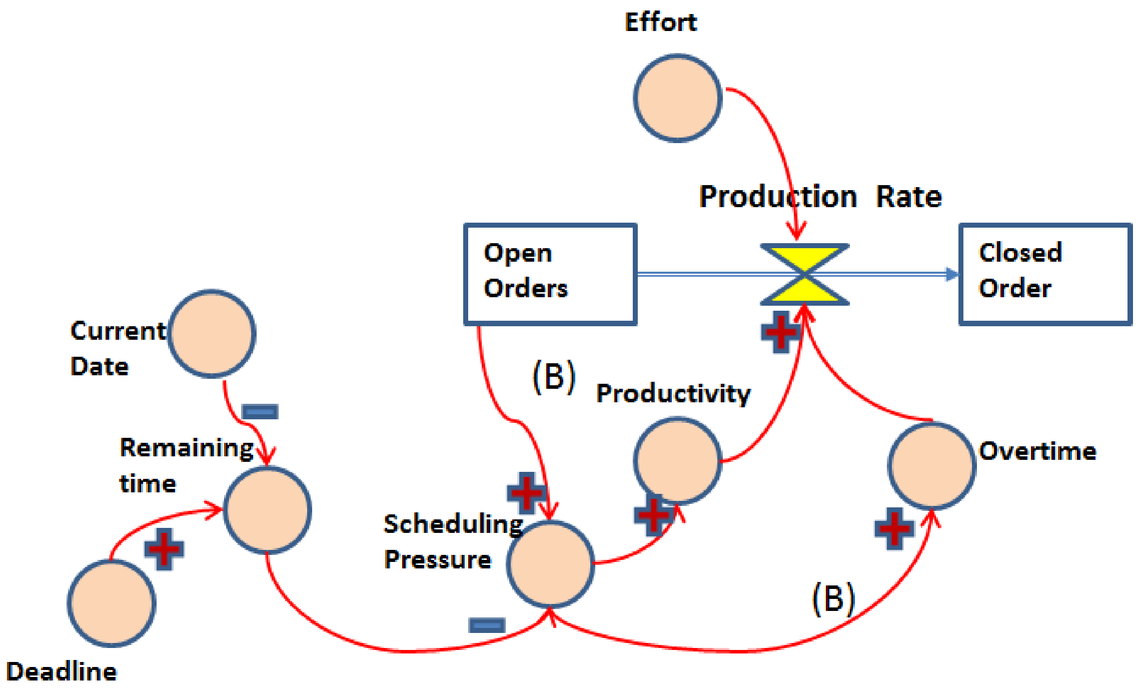


- Converters either represent parts at the boundary of the system (i.e. parts whose value is not determined by the behaviour of the system itself : current date or remaining time) or they represent parts of a system whose value can be derived from other parts of the system.

CONNECTORS: Much like in causal loop diagrams the connectors of a system show how the parts of a system influence each other. Stocks can only be influenced by flows (i.e. there can be no connector that connects into a stock), flows can be influenced by stocks, other flows, and by converters. Converters either are not influenced at all (i.e. they are at the systems boundary) or are influenced by stocks, flows and other converters.

SOURCE / SINK: Sources and sinks are stocks that lie outside of the models boundary – they are used to show that a stock is flowing from a source or into a sink that lies outside of the models boundary. On diagrams, sources and sinks are represented by small clouds.

Understanding stock flow diagram



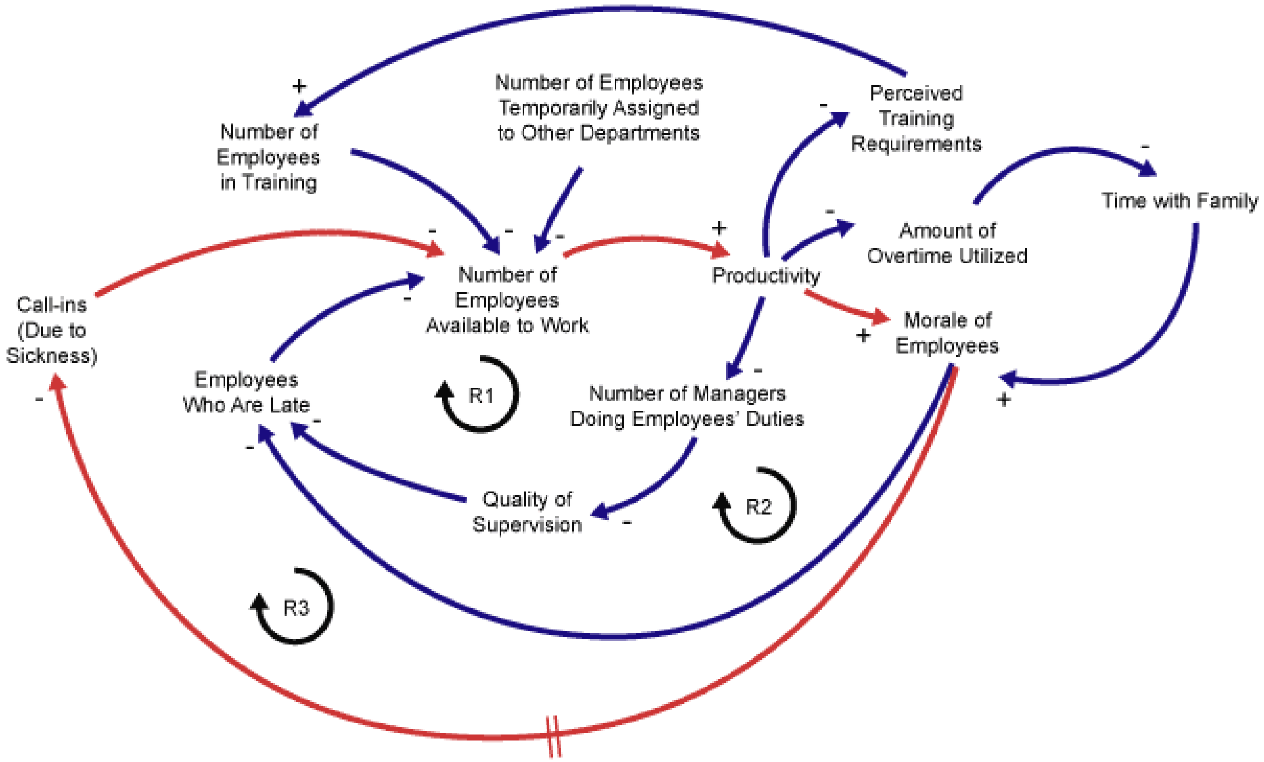
Part	Category	Comment
Open Tasks	Stock	Clearly the number of open tasks must be a stock – on any given day we cannot know how many open tasks remain without either explicitly counting them or explicitly keeping track of our progress.
Completion Rate	Flow	The completion rate is the only element that has a direct impact on a stock.
Deadline	Converter (Boundary value)	The deadline is a boundary value, because it is set from the outside. We represent these kinds of values using converters that have no further inputs.
Current Date	Converter (Boundary value)	The current date is also a boundary value, albeit not a constant one.
Remaining Time	Converter	This is an auxiliary which can be derived from the current date and the deadline.
Schedule Pressure	Converter	The schedule pressure can be calculated at any time given the remaining time and the number of open tasks.
Productivity	Converter	Productivity and Overtime are conceptually much harder to model than the other elements. To keep our model simple initially, we assume that my current productivity only depends on the current schedule pressure and not on my past behavior. We make the same assumption about the overtime (i.e. the normal workday plus overtime) I work.
Overtime	Converter	

Causal loop

Causal loop diagrams provide a language for **articulating the understanding of the dynamic**, interconnected nature of the system and its emerging properties. From a System Dynamics perspective Causal Loops Diagrams (CLD) are used to articulate models with the objective:

- **Understanding critical problems and potential leverage points.**
- **Elevating system capability and potentiality.**
- **Defying ideal system potential based on system purpose.**
- **Use CLD to identify critical variety attenuators and amplifiers.**

A causal loop diagram is a simple map of a system with all its constituent components and their interactions. By capturing interactions and consequently the feedback loops a causal loop diagram reveals the structure of a system. By understanding the structure of a system, it becomes possible to ascertain a system’s behaviour over a certain time period. Causal Loop is also fundamental in documenting systemic thinking in terms of cause and effect of related elements.


Number of Employees in Training
Number of Employees Temporarily Assigned to Other Departments
Perceived Training Requirements
Time with Family
Amount of Overtime Utilized
Call-ins (Due to Sickness)
Number of Employees Available to Work
Productivity
Morale of Employees
Employees Who Are Late
R1
Number of Managers Doing Employees' Duties
Quality of Supervision
R2
R3

A diagram that shows causal links among actions, information, and consequences. Sometimes referred to as the influence diagram or directed graph.

Causal Loop Diagram is a useful way to represent interrelationships and system structure of the parts that make up the system.

System Archetypes

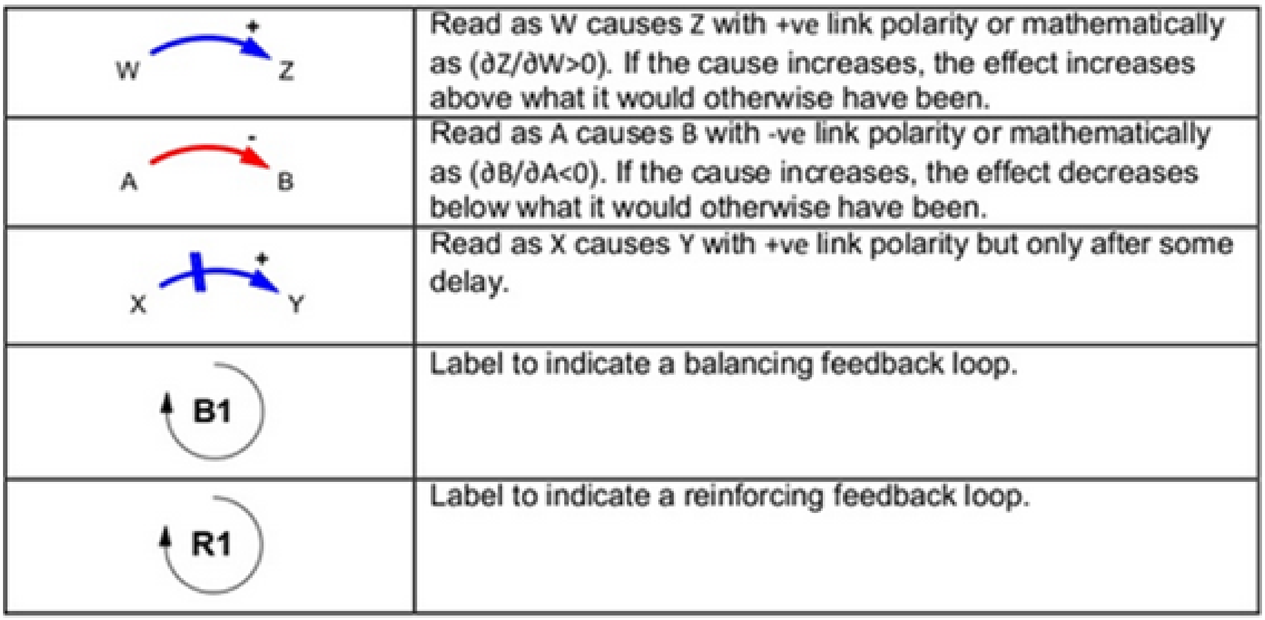
The Systems Archetypes are patterns of behaviour that emerge from the underlying system Structure. They can be used diagnostically to reveal insights into the structure that already exists, or prospectively to anticipate potential problems and / or problem symptoms.

- Archetypes do not describe any one problem specifically. They describe families of problems and / or families or resolvers.
- Generically. Their value comes from the insights they offer into the dynamic interaction of complex systems.
- System archetypes are a class of tools that capture the "common stories" in systems thinking.
- A powerful tools for diagnosing problems and identifying high leverage interventions that creates fundamental change.
- Casual Loop fundamentally a qualitative method to understand how an element of the system seek equilibrium (pre-defined targets) or amplifies change (achieve desired objective):
    - Reinforcing loop to amplifies change.
    - Balancing loop that seeks equilibrium over time by reaching target.

Characteristics of a causal loop diagram:

- Defining cause and effect though sequence for the problem under study:
- Logical (efficacy of government management influence economic leverage, governments are the most powerful / used by the people Mafia within a respective territory).
- Illogical (high level of corruption effect on government expenditure which influence taxation, high taxation influences disposable income which in turn influence private consumption).
- Variable – an element in a situation which may act or be acted upon that can vary over time.
    - Vary up or down over time (not events): Factory finished goods inventory

  - Nouns or nouns phrases. Avoid verbs and action phrases, the action is conveyed in the loop's arrows: Safety Stock
  - Chose the more positive sense: usage of growth versus contraction
- Links and arrows – shows relationship and the direction of influences between variables
- S's and O : shows the way one variable moves or changes in relation to other
  - **S –** Same direction (or +)
  - **O –** Opposite direction (or –)
- Causal Loop Objects used for modelling

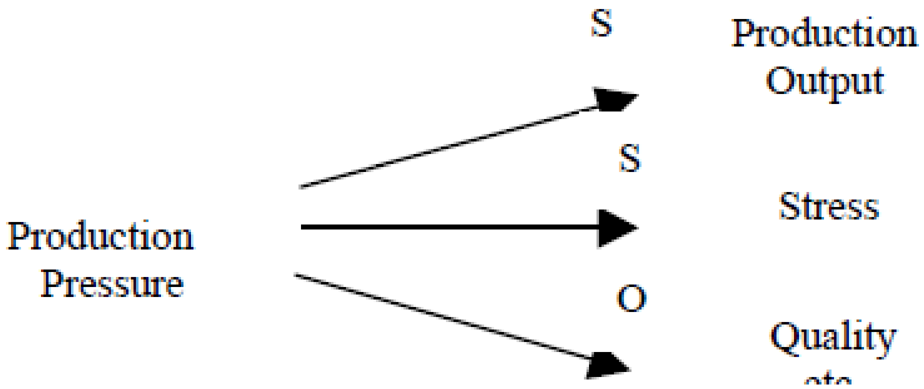


W + Z	Read as W causes Z with +ve link polarity or mathematically as (∂Z/∂W>0). If the cause increases, the effect increases above what it would otherwise have been.
A - B	Read as A causes B with -ve link polarity or mathematically as (∂B/∂A<0). If the cause increases, the effect decreases below what it would otherwise have been.
X + Y	Read as X causes Y with +ve link polarity but only after some delay.
B1	Label to indicate a balancing feedback loop.
R1	Label to indicate a reinforcing feedback loop.

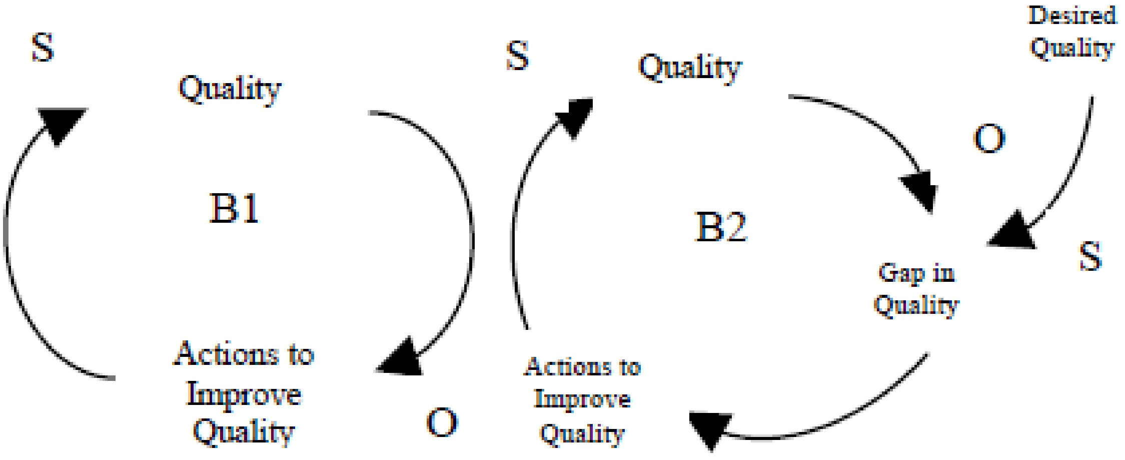
Feedback loops

- B] **Balancing** feedback loop that seeks equilibrium.
  - Goal seeking feedback or balancing loop.
  - Actions are directed toward an objective or target.
  - Where feedback reduces the impact of a change.
  - Have an odd number of "–" signs.
  - Tend to produce "stable", "balance", "equilibrium" and "goal-seeking" behavior over time.
- R] **Reinforcing** feedback loop that amplifies reinforcing change.

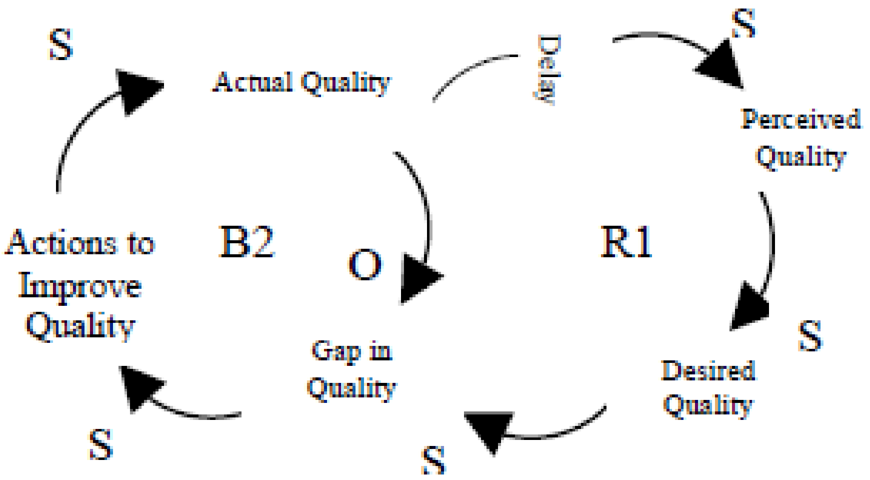
  - Reinforcing loop.
  - Vicious cycle or virtuous cycle.
  - Growth generating mechanisms.
  - Where feedback increases the impact of a change,
    - Have an even number of '–' signs.
    - Some quantity increase, a "snowball" effect takes over and that quantity continues to increase.
    - Generate behaviors of growth, amplify, deviation, and reinforce.
- **Think of the possible unintended consequences** as well as the expected outcomes for every course of action included in the diagram. For example, an increase in "Production Pressure" may increase "Production Output," but it may also increase "Stress" and decrease "Quality".



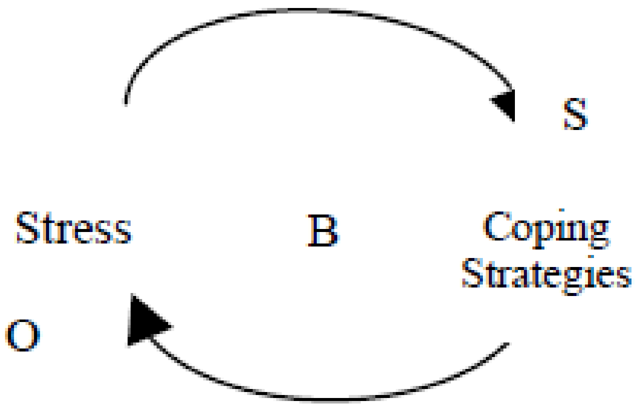
- **All balancing loops are goal-seeking processes**. Try to make explicit the goals driving the loop. For example, loop B1 may raise questions as to why increasing "Quality" would lead to a decrease in "Actions to Improve Quality" By explicitly identifying "Desired Quality" as the goal in loop B2, we see that the "Gap in "Gap in Quality" is really driving improvement actions.



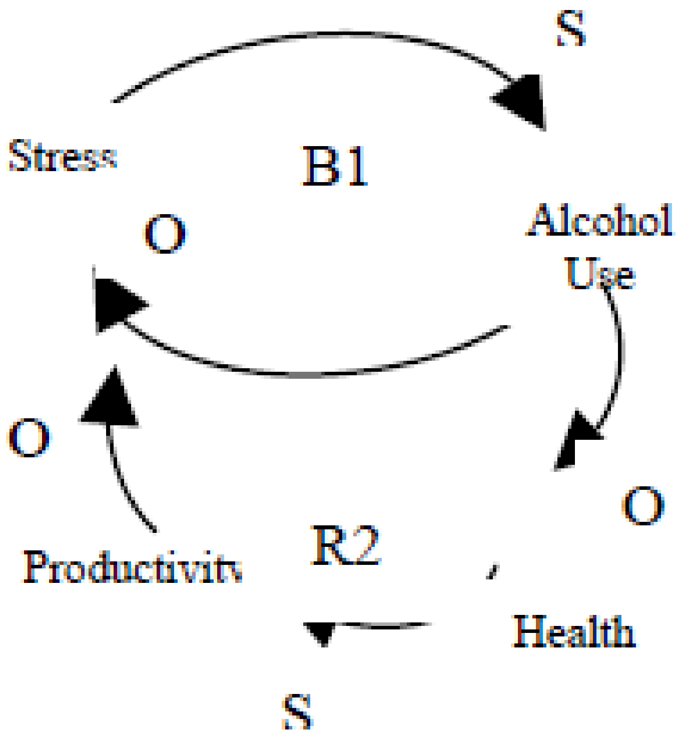
- **Distinguishing between perceived and actual states**, such as "Perceived Quality" versus "Actual Quality" is important. Perceptions often change slower than reality does, and mistaking the perceived status for current reality can be misleading and create undesirable results.



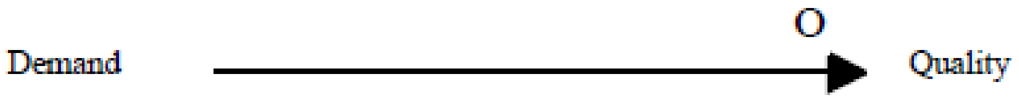
- **If a variable has multiple consequences,** start by lumping them into one term while completing the rest of the loop. For example, "Coping Strategies" can represent many different ways we respond to stress (exercise, meditation, alcohol use, etc.)

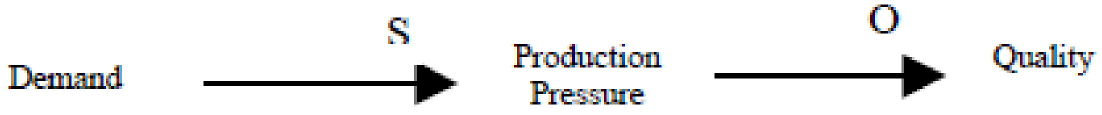


- **Actions almost always have different long-term and short-term consequences.** Draw larger loops as they progress from short-to long-term processes. Loops B1 show the short-term behavior of using alcohol to combat stress. Loop R2, however, draws out the long-term consequences of this behavior, showing that it actually increases stress.

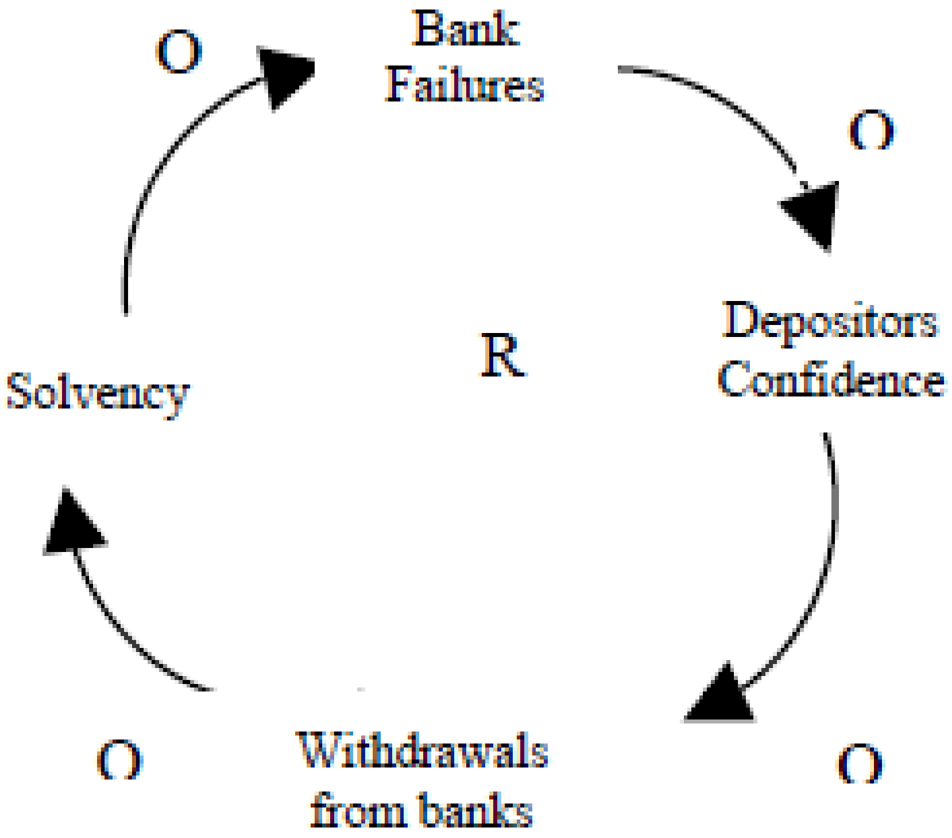


- **If a link between two terms requires a lot of explanation to be clear,** redefine the variables or insert an immediate term. Thus, the relationship between “Demand” and “Quality” may be more obvious when “Production Pressure” is inserted between them.

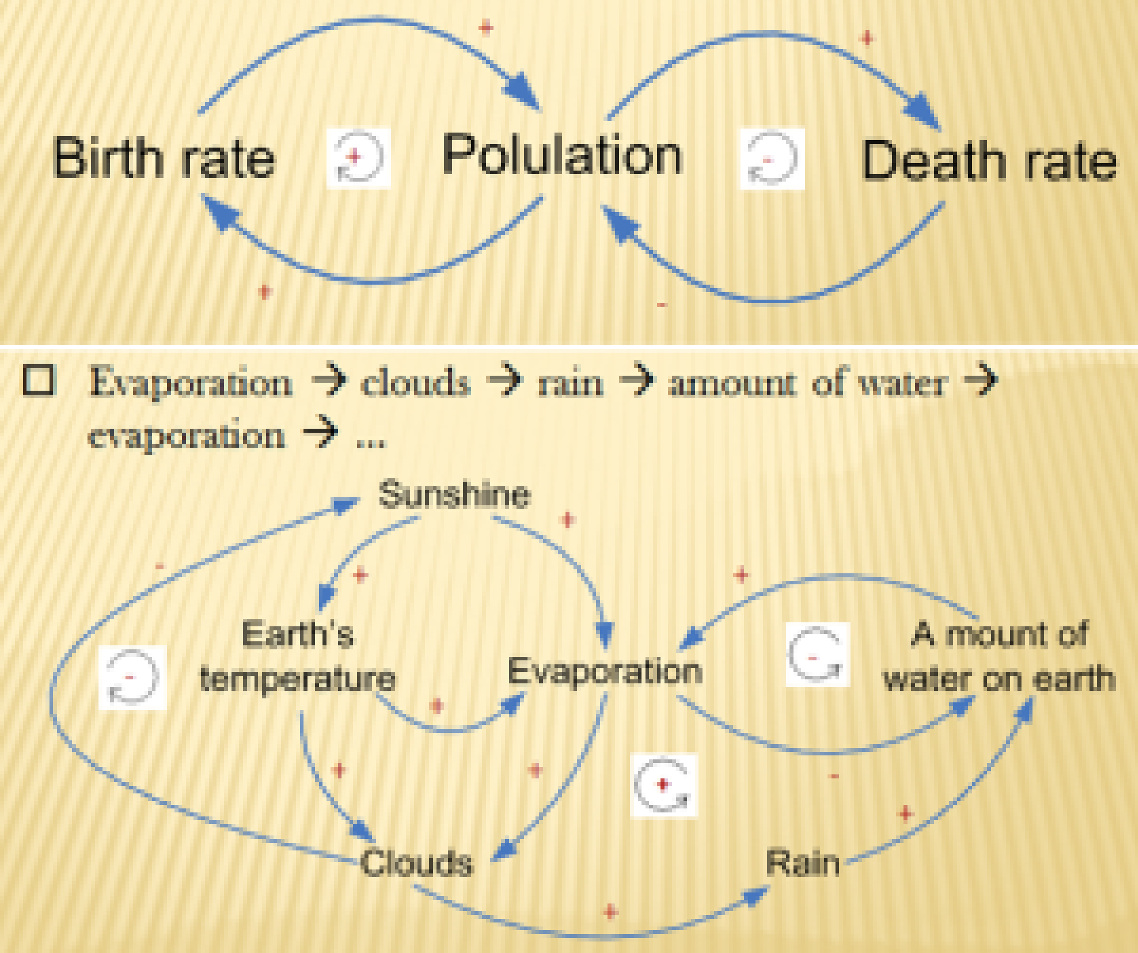




- **A shortcut determining whether a loop is balancing or reinforcing is to count the number of "o's" in the loop**. An odd number of "o's" indicates a balancing loop (i.e. an odd number of U-turns keeps you headed in the opposite direction); an even number or no "o's" means it is a reinforcing loop. CAUTION: After labeling the loop, you should always read through it to make sure the story agrees with your R and B label.

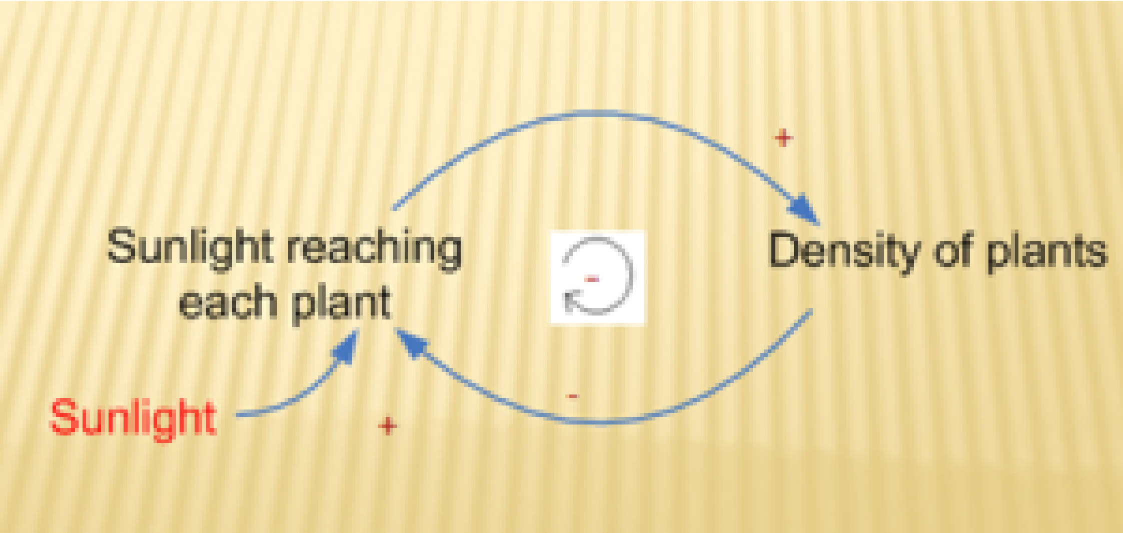


- **LD] Loop Dominance:**
    - There are systems which have more than one feedback loop within.
    - A particular loop in a system of more than one loop is most responsible for the overall behavior of that system.
    - The dominating loop might shift over time.
    - When a feedback loop is within another, one loop must dominate.
    - Stable conditions will exist when negative loops dominate positive loops.
    - Example combined feedback.



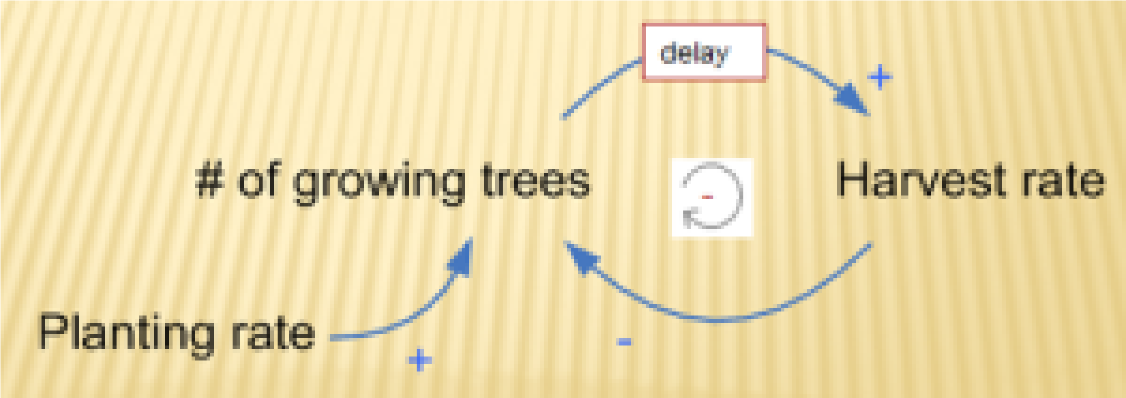
☐ Evaporation → clouds → rain → amount of water → evaporation → …

- Exogenous items.
    - Items that affect other items in the system but are not themselves affected by anything in the system.

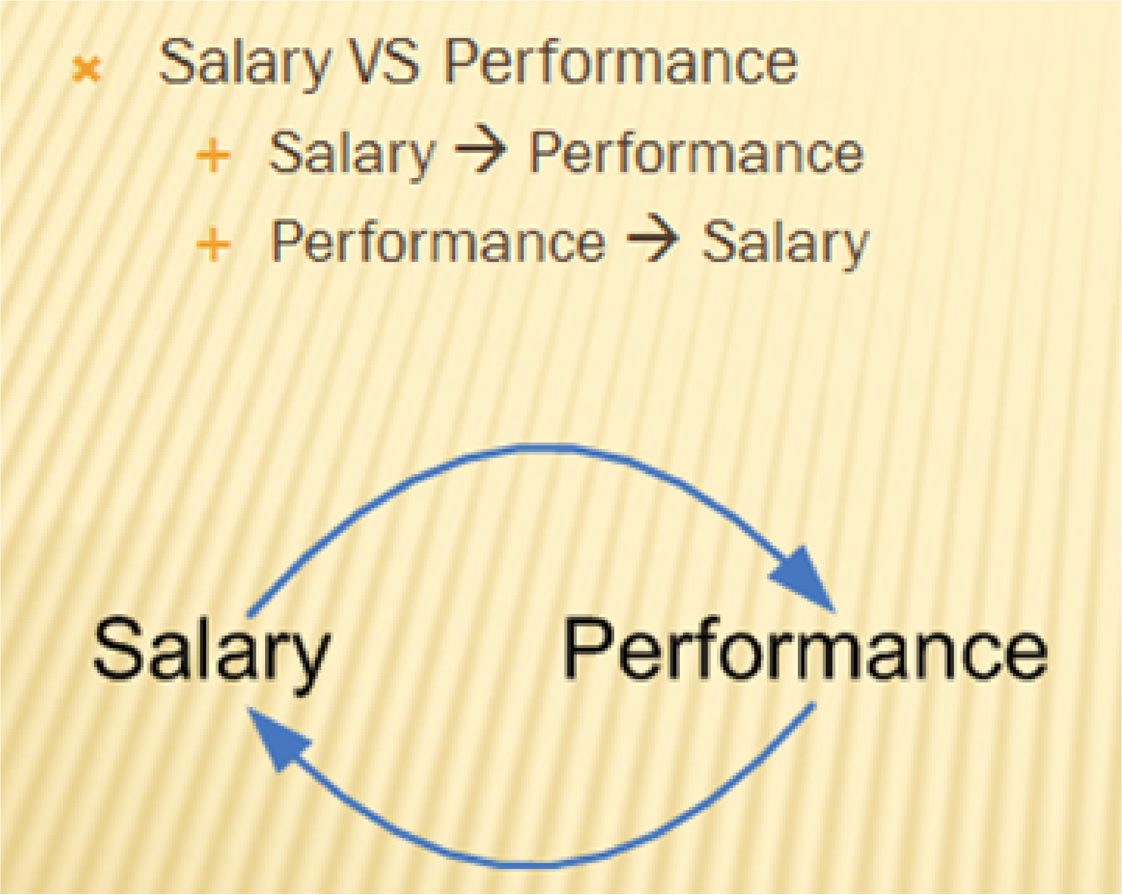


  - Arrows are drawn from these items but there are no arrows drawn to these items

- Delays:
  - Systems often respond sluggishly.
  - From the example below, once the trees are planted, the harvest rate can be ‘0’ until the trees grow enough to harvest.

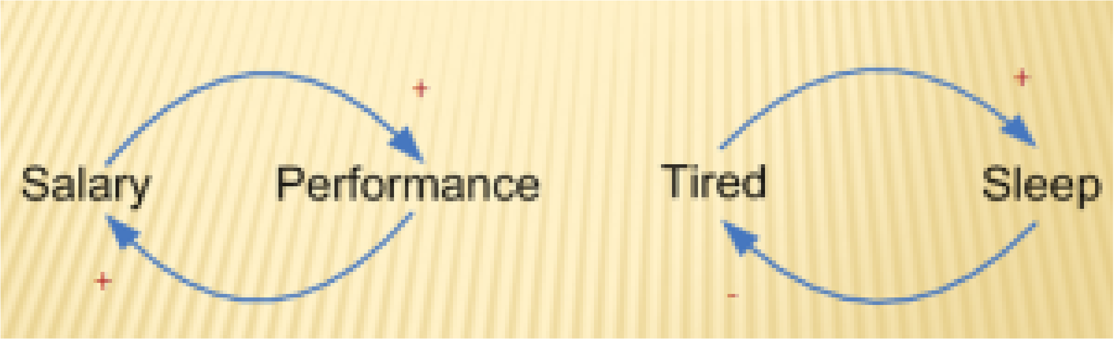


- Feedback cause and effect. An initial cause ripples through a chain of causation ultimately to re-affect itself.

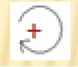


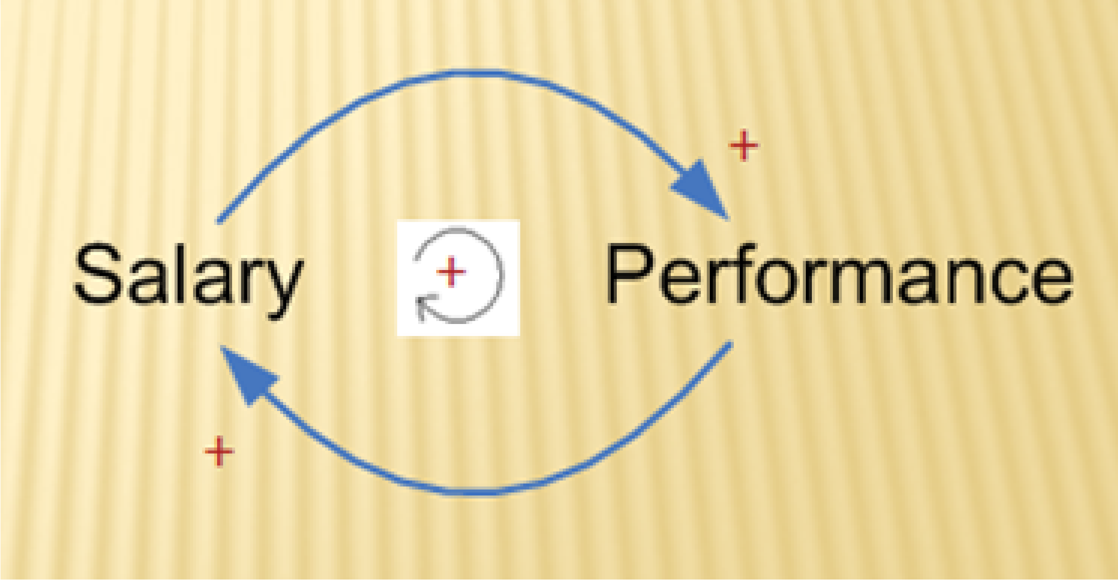
- Salary VS Performance
  - Salary → Performance
  - Performance → Salary

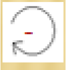
- Causal Loop polarity:
  - Signing: Add a ‘+’ or a ‘–’ sign at each arrowhead to convey more information.
  - A ‘+’ is used if the cause increase, the effect increases and if the cause decrease, the effect decreases.
  - A ‘-’ is used if the cause increases, the effect decreases and if the cause decreases, the effect increases.
    Positive and negative feedback loops:

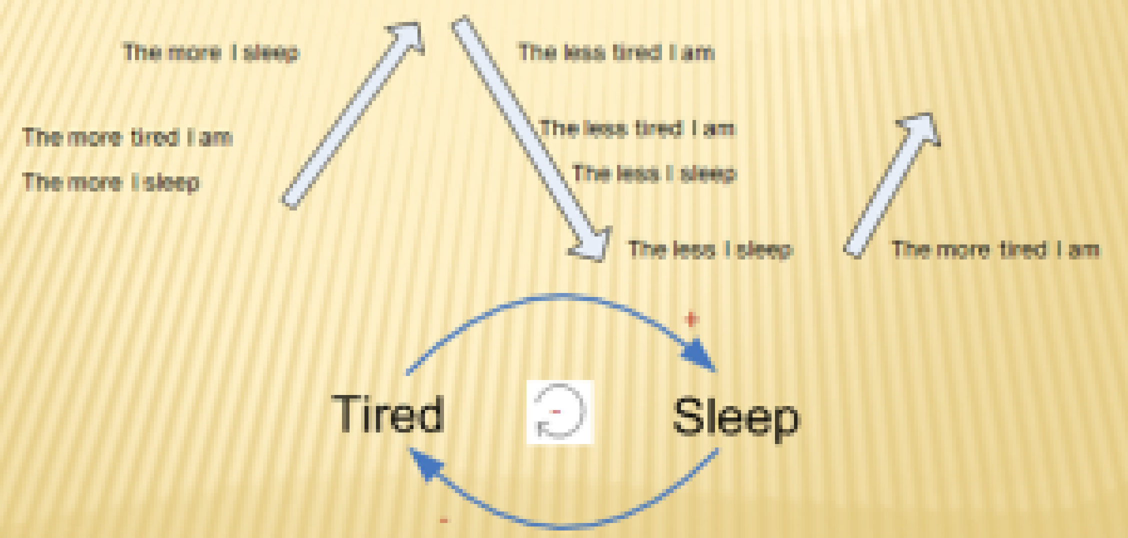


- **Positive and negative** feedback loops:

  - **Positive** feedback loops
    - Have an even number of '–' or '+' signs
    - Some quantity increase, a "snowball" effect takes over and that quantity continues to increase
    - The "snowball" effect can also work in reverse
    - Generate behaviors of growth, amplify, deviation, and reinforce
    - Notation: place  symbol in the center of the loop
    - Example: Salary > Performance, Performance > Salary



- **Negative** feedback loops
  - Have an odd number of "–" signs
  - Tend to produce "stable", "balance", "equilibrium" and "goal-seeking" behavior over time
  - Notation: place  symbol in the center of the loop
  - Example: Tired > Sleep, Sleep > Tired



Constraints

A constraint is a limitation, imposed by outside circumstances or by system behavior (ourselves), that materially affects our ability to do something and limits a person or an organization in achieving their goal. Constraints directly impact systemic **capability and potentiality**.

There is a subtle difference between a **constraint** and a **bottleneck**.

A bottleneck (resource) is a resource with capacity less or equal to demand while a constraint is a limiting factor to organization's performance, an obstacle to the organization achieving its goal.

A constraint can be called bottleneck but a bottleneck is not always a constraint.

Key Considerations:

- By managing organization as a whole, instead of separate parts, understand how everything is connected within the organization, understating dominant influences that determine conditions (production output, inventory, sales ect…) by identifying critical constraint and managing everything around the constraint efficiently and effectively **transforms potential into energy**.
- **By making a constraint an opportunity**, implies seeing it as an opportunity, not punitive restriction, and using it as a stimulus to see a new or better way of achieving organizational goals.
- When we face the problem of managing finite resources, synergy and synchronization is of fundamental importance to transform its potential ; maximize throughput therefore optimize its performance; **freeing up energy that otherwise would be lost**.

Constraints fall into four different groups:

- **Constraints of foundation** (where we are limited in something that is usually seen as a foundation element for success); internet selling does but provide the buyers to touch and feel. Policy decision such as aligning product development around specific operating system (Nokia).
- **Constraints of resource** such as facilities, manufacturing resources, people etc…
  A constraint of resource relates to what generates output.
- **Constraints of method** (where we are limited by having to do something in a certain way). Typically entrenched business processes based on ERP system ways of working that influence effective exploitation of resources and time.
- **Constraints of time** (where we are limited in the amount of time we have to do something)
- As it is the case in many companies, top management set local productivity objectives creating whole system productivity issues.
- **Constraints of management**; limitation of the system due to management capacity or management attention. Management has a limited availability to deal with issues and control in their system sphere. Capacity management implies how many different issues can be handled over a period of time. A fundamental aspect to viability relates to autonomy; the ability of operational units to operate in autonomy within predefined control criteria freeing up management effort to deal with more complex and serious issues.

Examples of Constraints:

1. Machine Equipment capacity
2. Austerity; Government budget deficit or debt to GDP ratio
3. Process: the way processes is structured
4. Information Systems
5. Facilities

One of the key aspects around effective governance is to continuously review constraints and bottlenecks and related throughput (effective throughput implies producing the right things) by applying five focusing steps of based on Theory of Constraints:

1. Identify the constraint
2. Exploit the constraint

3. Subordinate everything to the constraint
4. Elevate the constraint
5. Prevent inertia to become the constraint

The above is fundamental in maximizing potentiality, capability, profitability, efficiency and effectiveness.

Feedback

A System is defined as a set of interrelated components that work together to achieve common goals, accepting input data (input) and producing results (output) in an organized transformation processes.

Self-regulation describes the ability of a system **to 'manage' itself (feedback)** towards its purpose or goals despite environmental disturbances based on ether balancing or reinforcing feedback:

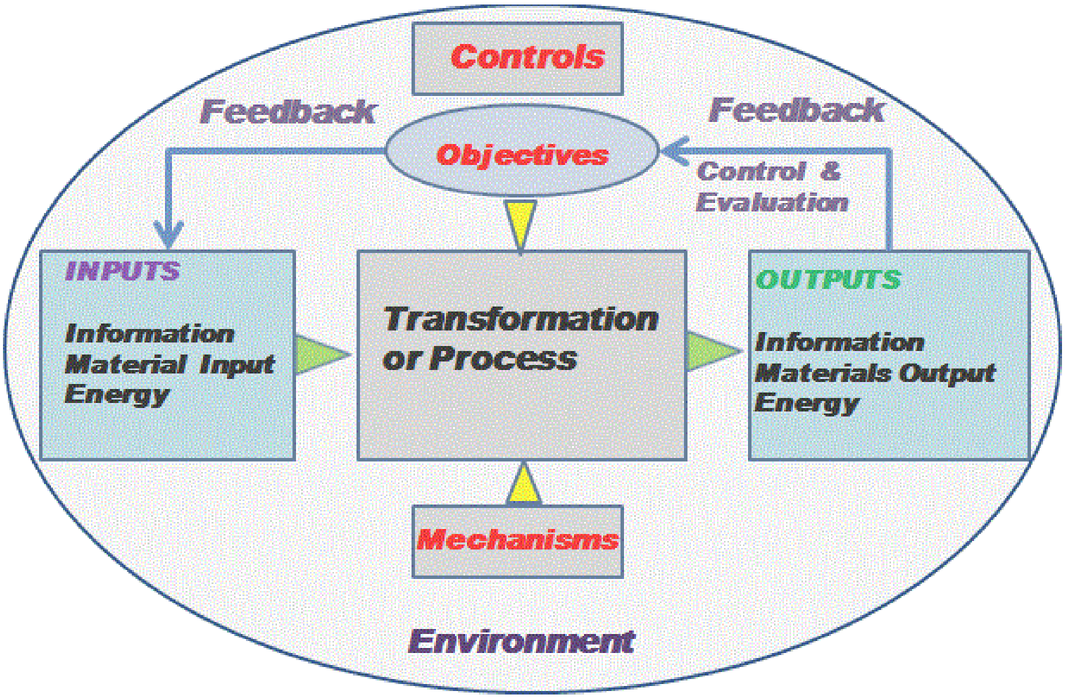
- **First order feedback whereby the goal is determined externally to it.**
- **Second order feedback where system is capable of choosing between variety responses to environmental changes in order to achieve its goal.**
- **Third order system is one that is capable of changing the goal state itself in response to feedback process determining the goal internally s opposed to externally.**

The properties of the whole are superior to and different from combined properties of the parts.

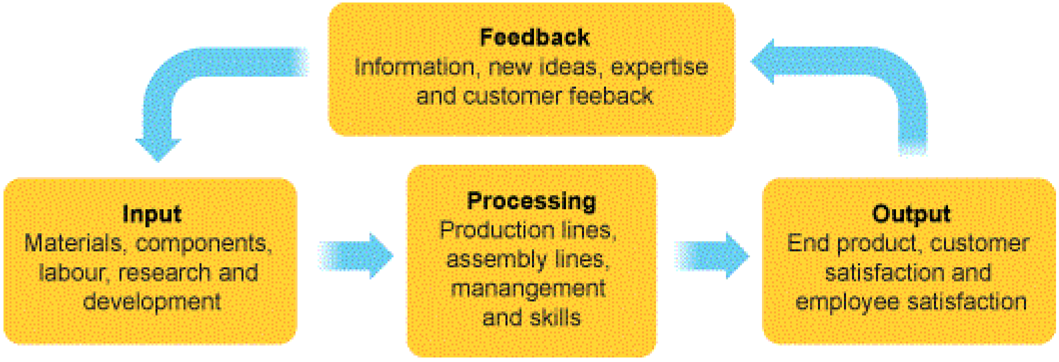
A system consists of the following functions:

- Input and Output
  - Involve collection / acquisition and assembly of the elements that enter the system to be processed.
  - Example: raw materials, energy, human effort are basic components of the production system;
- Processing (Processor operations)
  - Involves the transformation process which converts the input data into a finished product
- Output

    - The result of the transformation process, for example, the finished product or service
- Control
    - What control a process
    - Working procedure
    - Feedback
- Mechanism
    - Resources used for the conversion process
    - Equipment and facilities
    - People
- Environment
    - Customer, vendors, controlling authorities, competitors
- Feedback
    - Is the return or influence the outputs cause the entrances to balance the functioning of the system



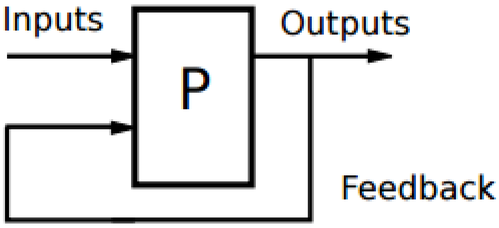
The feedback mechanism is a communication between the output and the system input and the main functions of feedback is to control the systems output, maintain the balance and survival.


Feedback
Information, new ideas, expertise and customer feeback
Input
Materials, components, labour, research and development
Processing
Production lines, assembly lines, manangement and skills
Output
End product, customer satisfaction and employee satisfaction

Feedback is a method of controlling a system by reinserting into it the result of its past performance (Norbet Wiener).

Feedback key propose is also to ensure homeostatic balance: maintaining stability. Negative feedback is a central homeostatic and cybernetic concept, referring to how an organism or system automatically opposes any change imposed upon it. Negative **feedback arises out of balances between forces and factors that mutually influence each other.** To illustrate several of its important characteristics, we can regard a car and its driver as a unified, complex, homeostatic or "goal-seeking" system in that it seeks to keep the car moving on track.

- Oscillation is a common and necessary behavior of many systems whereby abrupt negative feedback, however, usually over-corrects. A negative feedback, if it is as large as the disturbance **that triggered it, may become an impressed change** in the direction opposite to that of the original disturbance. Negative feedback takes time and such a time lag is an essential feature of many natural systems. **This may set the system to oscillating above and below the equilibrium level**.



A feedback loop where the outputs of a process are available as causal input to that process. The causal input (cause and effect of related elements) influencing the process. The influence can either be reinforcing (positive) or balancing (negative).

Feedback loops control a system's major dynamic behavior. A feedback loop is a series of connections causing output from one part to eventually influence input to that same part. This circular flow results in large amplification, delay, dampening effects, which is what causes the gross behavior of the system. Every part is involved in one or more feedback loops. Systems have more feedback loops than parts, which causes unimaginable complexity. Feedback loops are the main reason a system's behavior is emergent.

Systems contains only two kinds of feedback loops: reinforcing and balancing, also called positive and negative feedback loops. Complex systems are typically composed of multiple interacting feedback loops: some negative some positive.

Positive feedback result in escalation / growth while negative feedback result equilibrium / homoeostasis and oscillation.

A feedback loop occurs when a change in something ultimately comes back to cause a further change in the same thing. If the further change is in the same direction it's a positive or **reinforcing loop**. If it's in the opposite direction it's a negative or **balancing loop**, also called a goal-seeking loop.

Understanding feedback characteristics enables efficient design of feedback:

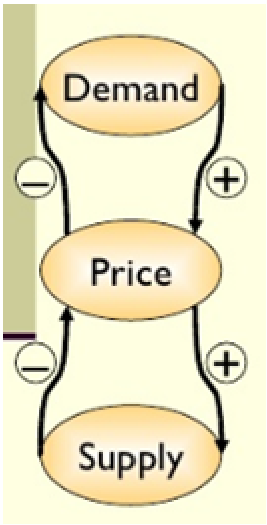
- **Positive feedback:**
    - Increasing returns.
    - A small change is amplified not corrected by feedback.
    - Changes grow without limit until some other factor intervenes.
    - Pairs of positive feedback systems can oscillate between two unstable states.
    - Examples
        - Interest rates.
        - Birth rate.
- **Information Flow**
    - Control Information.
        - Information about what has been achieved in the output is fed back to allow the process to be tuned.
        - Without this information no learning or improvements can take place over time.
        - The cost and energy involved feedback effect the efficiency of the system.
        - Within social process feedback has to be interpreted.
    - Issues.
        - Only reasonably linear processes benefit from simple feedback.
        - Discontinuation in system behavior may be more important than continuous.
        - Gain and Delay.
        - Delay : The delay that is introduced between the output to when its feedback into the input. Long delay creates system instability so that it cannot be controlled by its mechanisms impacting resilience. Medium delay produces oscillations while short delay gives smooth response converging on the desired output.
    - Gain : The gain of negative feedback process is the scale of the version of the output fed back into input.
        - Simple Feedback.

    - Process Control: Information from downstream process is fed back upstream. From simple input-process-output model measure the output and compare with desired output values. Use the feedback to adjust the input for subsequent process.
  - Example
    - Mechanical – thermostat controlling a central heating system.
    - Economics – Equilibrium of supply and demand via price.
- **Goal directed behavior**
  - **Establish the goals**
    - Establish set of measure or observations that indicate progress towards the goal.
    - Verify what has been achieved in achieving the goal.
    - If necessary change the goal or change the measure.
    - Carry-out actions that converge towards the goal.
- **Examples**
  - Central heating system.
  - Targets in managing the economy.
- **Controlling Systems**
  - **Useless Controls**
    - Control action that only seem to produce the required behavior.
    - Control action working against the logic of the system (its purpose).
    - Control actions that are subverted by other actors in the system.
  - **Subtle intervention**
    - Adjustment or additions simple rules (variety amplifies).
    - Making the connections between actions and system purpose more transparent.
- **Emergent behavior**
  - The behavior of the system cannot be predicted on the basis of the behavior of the elements.

  - Intervention in the system have inherently unpredictable outcomes.
  - If individuals or their organization is incapable of associating effects with their causes then learning and adaptation is not possible and both will continue repeating same errors.

Causal Relationship related to Feedback Using System Model

According to this model the function of price in a market system is as follows:



- It is an effect of given relationship between Supply and demand.
- At the same time it is a causal relationship the levels of supply and demand.

Thus sometime the market forces have the effect of balancing supply and demand and stabilizing prices.

Understanding the limitation of system model:

- Sometimes difference in prices are not reflect to changes to demand and supply.
  - **It can be elastic: responds quickly.**
  - Inelastic : responds weakly, slowly or not at all.
- Sometimes changes in supply and demand are not reflected in the prices.
- Sometimes there are other systemic stuff (market turbulence) going on that the effects of market forces are obscured.

Designing feedback:

According to Goetz, a feedback loop involves four stages:

1. The data, a behavior or evidence.
2. Relaying the information to the person in a context that makes it emotionally resonant or relevance.
3. The paths ahead the information illuminates, or consequence.
4. The moment when the individual can recalibrate a behavior, and take action.

Feedback cannot influence the past but only the future: therefore feedback design must consider those transformation processes that that need to be adjusted to achieve desired objectives.

Variety engineering

Any organization for it to be viable it must be capable of dealing with the complexity of its environment. Organizations are not able to create the same amount of complexity internally as their environment expose: **only variety absorbs variety (Beer)** therefore to **cope** with complexity, the variety the organization can produce has to be amplified towards the environment at the least possible costs and the variety that environment exposes has to be attenuated towards the organization.

Variety is the measure of the number of different states in system. The variety of system therefore depends on the context in which it is embedded and also who is observing that system. The larger the variety of actions available to a control system, the larger the variety of **perturbations (deviation/disturbance)** from stated goal and it is ability to compensate.

The key aspect of variety engineering is not about counting of possible states of a system but rather matching the possible states. The proliferation of variety in complex systems makes it difficult or rather nearly impossible to control therefore effective control requires capability to create a **level of variety** through regulative action which matches the variety of complex system **to be regulated**.

Control or regulation is most fundamentally formulated as a reduction of variety: perturbations with **high variety** affect the system's internal state (stability criteria), which should be kept as close as possible to the goal state, and therefore exhibit a **low variety**.

By 'viable system', Stafford Beer means a system capable of maintaining a separate existence, of surviving on its own'. Organisations are seen by Beer as systems, i.e. goal-directed entities made up of interacting parts, operating in an environment of some kind. **The central issue is: what form of internal 'architecture' is required if these systems are to be viable?** Beer's answer to this question is built upon a fundamental concept in cybernetic thinking, namely the Law of Requisite Variety (**LRV**) .

The Law of Requisite Variety, which states, to regulate a system, the regulator must be capable of generating at least as much variety as that exhibited by the system being regulated. Crudely-speaking, this law stipulates that the 'variety' of a 'control system' must equal or exceed the variety of that which is being regulated (variety is defined as the number of possible 'states' a system can be in). Therefore "**only variety absorbs variety**'.

Dealing with Complexity of the Environment:

Any organization if it is to viable it has to be capable of dealing with the complexity of its environment. Generally organization can hardly create same amount of complexity internally as their environment expose even though this is required because only variety absorbs variety' (Beer) . In order to absorb this variety the variety the organization can produce has to be amplified towards the environment.

The design of amplifiers and attenuators of variety is called variety engineering. System governance requires that managers deliberately design, control the diffusion of variety through the organization system.

Variety Attenuators

Attenuators are perceptual apparatus that filters (attenuates) the variety of the environment and only look for what is relevant and filter out (exclude) what is "irrelevant" . Attenuators select aspect of the signal which are relevant and discard aspects of what is not relevant. Market research is an example of carefully designed attenuators.

Variety Amplifiers

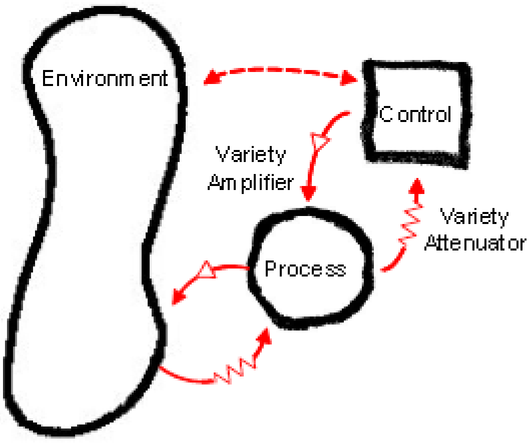
Operation and Management also amplify their own variety to increase their power over the environment by using intelligence to amplify the effects of management action.

Management and operations use intelligence to amplify the effect of relevant action with the sole purpose of maintaining their identity, in spite of perturbations in their environment in the face of pressures from their environment.

Attenuation is the attempt to stop or inhibit the proliferation of variety. Attenuation is effective if variety can be deflected and absorbed somewhere else in the system. Filtering is an example of a means of decreasing system variety; e.g., natural selection.

Absorption occurs when regulatory variety expands to match the amount of variety in the system, allowing the system to remain stable and continue to consistently reach desired states. An example of this is when a store has sufficient inventory and salespeople to successfully handle the needs of potential customers.

The three fundamental components management control, process, and environment must be maintained, dynamically, in homeostatic equilibrium in order to have a stable system.

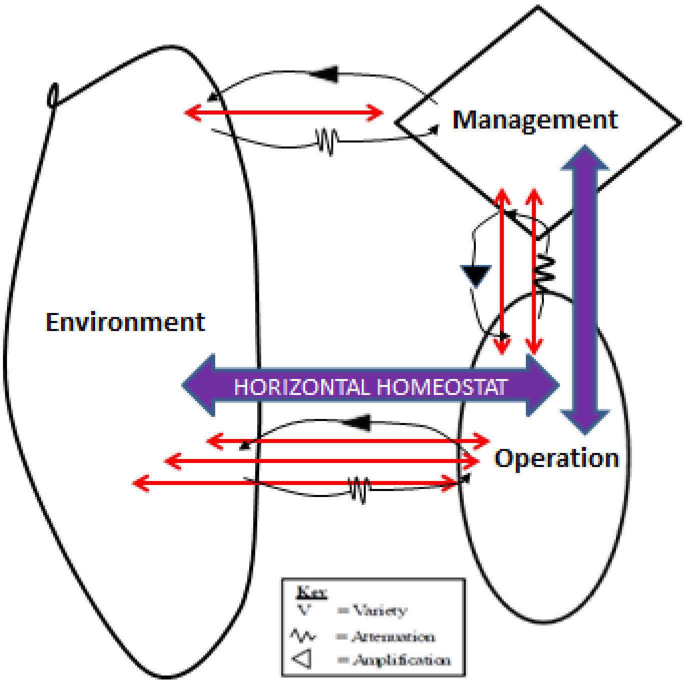


The figure above shows two types of arrows indicating the attenuation, or reduction, of variety, and the amplification, or increasing, of variety. **The variety surrounding** the environment will always be greater than that of **the operation** which in turn will be greater than that of the management of the operation.

The Operation can cope with its Environment, as long as it can successfully absorb the variety from it, by attenuating the incoming variety, and amplifying its own variety back to it. Likewise, Management can cope with the Operation as long as it can successfully absorb the variety from it, by attenuating the incoming variety, and amplifying its own variety back to it. If these requirements are met, the system can **maintain Homeostasis**.

Managing variety

In organizational terms, variety is about ensuring that the **capabilities of the systems** which **regulate** are **sufficient** to deal with the complexity of the problems which they have to deal with. There are two ways of coping with variety in complex systems:



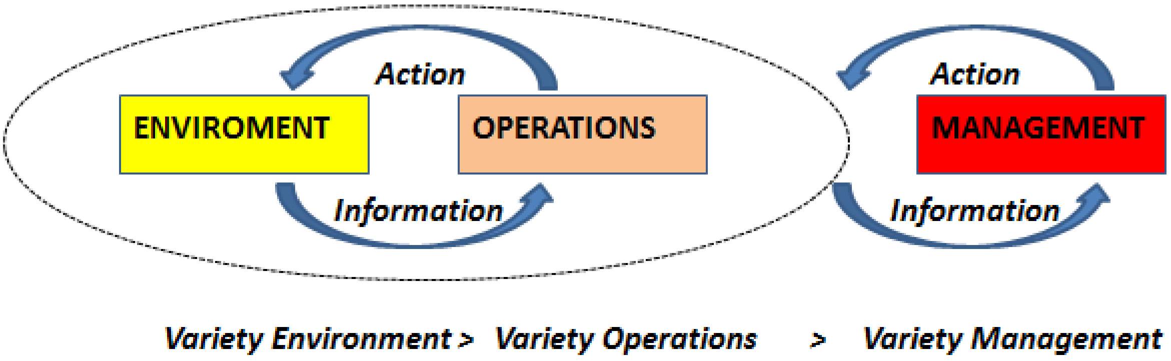
- Unfolding through recursive organizational structures
- Horizontal Attenuation or Amplification of variety

It is essential for any organization that it develops techniques for survival in a changing environment: it must adapt itself to its economic, commercial, social and political surroundings and **learn from experience**.

This means it can maintain itself in a state of equilibrium. If these requirements are not met, the system will become unstable, eventually leading to its collapse.

Organizational variety engineering fundamental objective is to balance varieties (Homeostatic) of the system which have different variety levels through attenuation and amplification:

- Environment which has huge variety : High Variety in respect to operations.
- Operation which has less than the environment: Low variety in respect to environment requiring amplification.
- Management even less variety of the operation and the environment.



VARIETY ENGINEERING

The challenge is to balance the varieties (high variety block to low variety block) of the operations & environment and management & operation. Possible examples of Variety Engineering:

To attenuate variety

- **Standardize** communication.
- **Standardize** processes.
- **Ignore** and filter out unimportant information, filter unnecessary detail.
- **Deal** with exceptions only.
- **Aggregate similar cases**.

- **Model** the environment and organizational behavior (causal loop diagram).
- To amplify variety.

Empower subordinates

- **Hire** more experienced employee.
- **Train** existing employees.
- **Collaborate** with external agents.
- **Customize** product/service offering.
- **Multiply** product/service offering or options to existing.
- **Combine** multiple products/services.

Variety needs to be managed actively along all communication channels between environment and operations, and operation and management.

Control or regulation is most fundamentally formulated as a reduction of variety: perturbations with high variety affect the system's internal state, which should be kept as close as possible to the goal (stability criteria) state, and therefore exhibit a low variety. One important implication of the law of requisite variety is that the member of a system that has the most flexibility also tends to be the catalytic member of that System.

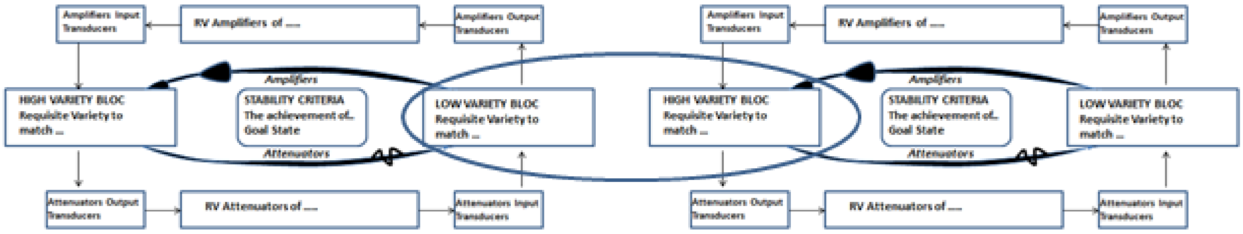
Attenuation means reduction of the variety of possible disturbances given the essential variables. Variety attenuators apply to disturbances coming from the environment to the organization. It is also possible to attenuate variety of possible disturbances coming from organization to its management.

The organization and management may use variety amplification to cope with residual variety of disturbances, Amplification means increasing regulatory environment need to cope with remaining disturbances given the selected variables and existing attenuators.

Amplification has two domains; amplification from the organization towards the environment as well as amplification from management towards organization.

Design framework with respect to variety engineering

The fundamental purpose with respect to variety engineering is to manage stability criteria between environment and operations, or operation and management to achieve homeostatic balance. The function of homeostasis aims at creating stability and not stagnation. Without stable reference point it is not possible to determine the amount of change and its direction (steering and governance) in an organizational system influenced by continuous changes.


Amplifiers Input Transducers
RV Amplifiers of ....
Amplifiers Output Transducers
HIGH VARIETY BLOC Requisite Variety to match ...
Amplifiers
STABILITY CRITERIA The achievement of.. Goal State
Attenuators
LOW VARIETY BLOC Requisite Variety to match ...
Attenuators Output Transducers
RV Attenuators of ....
Attenuators Input Transducers
Amplifiers Input Transducers
RV Amplifiers of ....
Amplifiers Output Transducers
HIGH VARIETY BLOC Requisite Variety to match ...
Amplifiers
STABILITY CRITERIA The achievement of.. Goal State
Attenuators
LOW VARIETY BLOC Requisite Variety to match ...
Attenuators Output Transducers
RV Attenuators of ....
Attenuators Input Transducers

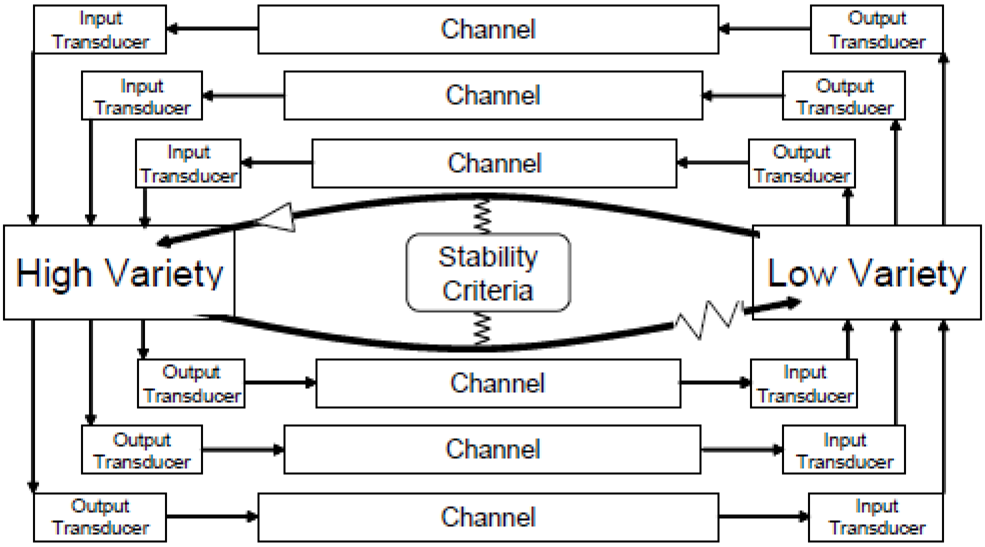
Homeostatic loop analysis has to cover complete system inclusive of environment, operation and management. Systemic imbalance is attained if homeostatic balance is only achieved between either environment and operation and not operation and management.

- Homeostatic balance between Environment (high variety) and the Operations (Low Variety). The Operation can cope with its Environment, as long as it can successfully absorb the variety from it, by attenuating the incoming variety, and amplifying its own variety back to it.
- Homeostatic balance between Operation (high variety blockS) and Management (Low variety block) Management can cope with the Operation as long as it can successfully absorb the variety from it, by attenuating the incoming variety, and amplifying its own variety back to it.

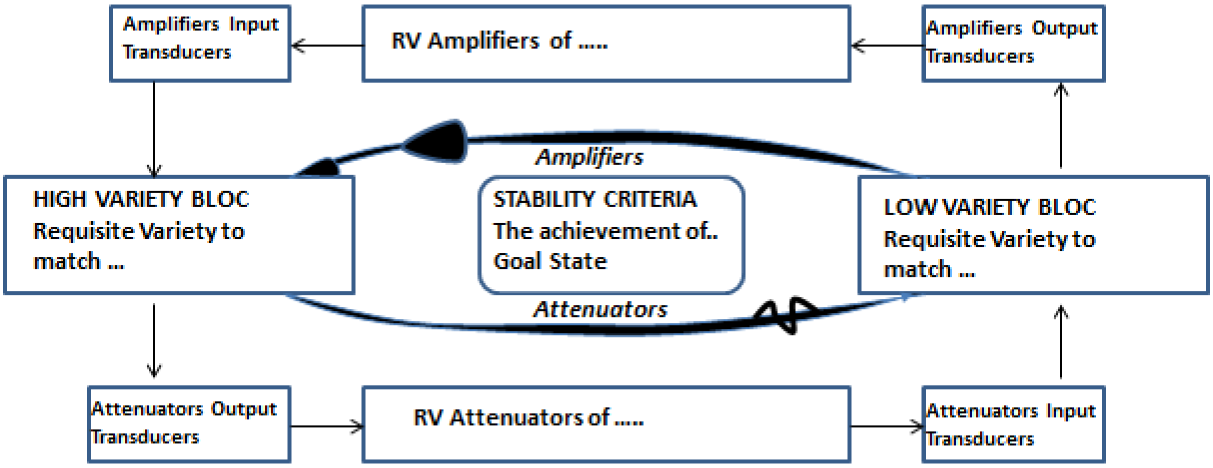
The organization and management may use variety amplification to cope with residual variety. Amplification means increasing regulatory environment need to cope with remaining disturbances given the selected variables and existing attenuators.

Amplification has two domains; amplification from the organization towards the environment as well as amplification from management towards organization.

The purpose of the homeostatic loop analysis is to achieve homeostatic balance within the stability criteria between high variety and low variety considering that from a complexity perspective it is generally not possible to define systemic responses for every possible disturbance.



Transducers encode or decode messages that cross a system boundary. Whenever the information carried on a channel crosses a boundary it undergoes transduction.

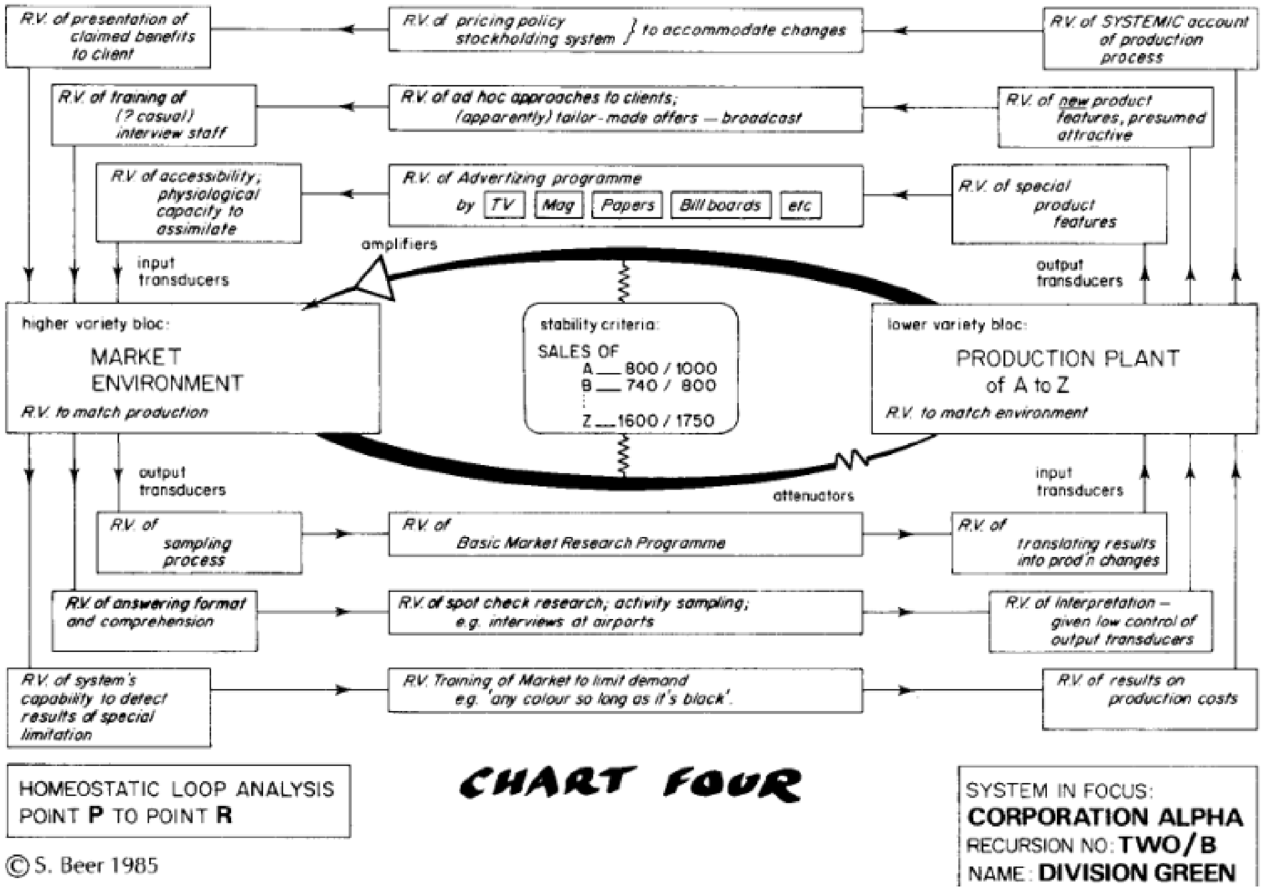

Amplifiers Input Transducers
RV Amplifiers of .....
Amplifiers Output Transducers
Amplifiers
HIGH VARIETY BLOC
Requisite Variety to match ...
STABILITY CRITERIA
The achievement of..
Goal State
LOW VARIETY BLOC
Requisite Variety to match ...
Attenuators
Attenuators Output Transducers
RV Attenuators of .....
Attenuators Input Transducers

Homeostatic Loop analysis schematics consists of the following elements:

- System in focus overview: With respect to vertical unfolding complexity define at the specific level of attention what it does and why and how.
- Recursion Number and name.
- Loop analysis point to point relationship : Environment to operations or Operation to Management.

- Attenuators and amplifiers are only possible given selected goals (defined stability criteria) Stability criteria: For the system in focus define the stability criteria. Examples Goal Sales or XXX for market XZY (relevant environment)
- High Variety Block : Requisite variety to match…
    - Attenuators Output transducers.
    - Attenuators channels.
    - Attenuators input transducers.
- Low Variety Block: Requisite variety to match.
    - Amplifiers output transducers.
    - Amplifiers channel.
    - Amplifiers input transducers.

An example of possible scenario. In this case it could be a global auto manufacturing company purpose is to supply new vehicles and support to the market such as spares and maintenance. One of the operational units relates to auto manufacturing and supply at the regression level of a specific country and target market (environment). The level of regression is unfolding complexity to level that the ideal stability criteria can be achieved with effective variety engineering. Multiple attenuators and amplifiers loops are put in place in order to achieve desired stability criteria.


R.V. of presentation of claimed benefits to client
R.V. of pricing policy stockholding system } to accommodate changes
R.V. of SYSTEMIC account of production process
R.V. of training of (? casual) interview staff
R.V. of ad hoc approaches to clients; (apparently) tailor-made offers — broadcast
R.V. of new product features, presumed attractive
R.V. of accessibility; physiological capacity to assimilate
R.V. of Advertizing programme by TV Mag Papers Bill boards etc
R.V. of special product features
amplifiers
input transducers
output transducers
higher variety bloc:
MARKET ENVIRONMENT
R.V. to match production
stability criteria:
SALES OF
A — 800 / 1000
B — 740 / 800
Z — 1600 / 1750
lower variety bloc:
PRODUCTION PLANT of A to Z
R.V. to match environment
output transducers
attenuators
input transducers
R.V. of sampling process
R.V. of Basic Market Research Programme
R.V. of translating results into prod'n changes
R.V. of answering format and comprehension
R.V. of spot check research; activity sampling; e.g. interviews at airports
R.V. of interpretation – given low control of output transducers
R.V. of system's capability to detect results of special limitation
R.V. Training of Market to limit demand e.g. 'any colour so long as it's black'.
R.V. of results on production costs
HOMEOSTATIC LOOP ANALYSIS POINT P TO POINT R
CHART FOUR
SYSTEM IN FOCUS:
CORPORATION ALPHA
RECURSION NO: TWO/B
NAME: DIVISION GREEN
© S. Beer 1985

The stability criteria goal states cannot exceed the agreed with meta mgt optimal system potentiality of the combined S1 of the recursive level in question.

This then implies a further homeostatic loop analysis between Operation (high Variety) and management (low variety) to define the stability criteria (goal state) of production based on recursive level system potentiality and available negotiated resources, compliance, quality etc…

The production goal state should allow for safety factor (achievable targets) knowing difficulty in **achieving optimal system performance**.

Effective homeostatic loops analysis provide for system ideal goals, adaptation initiatives (do the right things) in order to achieve overall homeostatic balance and viability. The goal states from ideal baselines for effective governance via **control tower** in order to continuously monitor the efficacy of the stated initiatives.

Key terms:

- **A System** is a group of interconnected elements which mutually influence one another through causal loops and feedback.

- **Variety** relates to the phenomena of change or variation within a system. Diversity is variety with respect to space.
- **Dynamic fluctuation** is variety with respect to time. Complexity and uncertainty are a result of the combination of both types of variety.
- **System variety** is the amount of potential variation within a system in a particular time and space. Too little variation and diversity leads to rigidity and stagnation. Too much diversity leads to instability and chaos.
- **Regulatory variety** relates to the number of actions or responses necessary to react appropriately to variation and direct the system to a positive outcome. Technological innovation is a means of increasing both regulatory variety and system variety.
- **Flexibility** is the potential for adaptive variation in a system. Flexibility comes from having sufficient system variety and regulatory variety.

A system may try to either attenuate or absorb diversity. Requisite variety has to do with the amount of flexibility **required to deal with change**.

Recursive systems

Organisations are complicated and complex. Any attempt from context perspective which is concerned with understanding systems must provide a means of looking at this complexity in manageable bits. Manageable from a VSM perspective implies vertical unfolding complexity where each level of recursion is considered as a ‘System in Focus’ and a viable system.

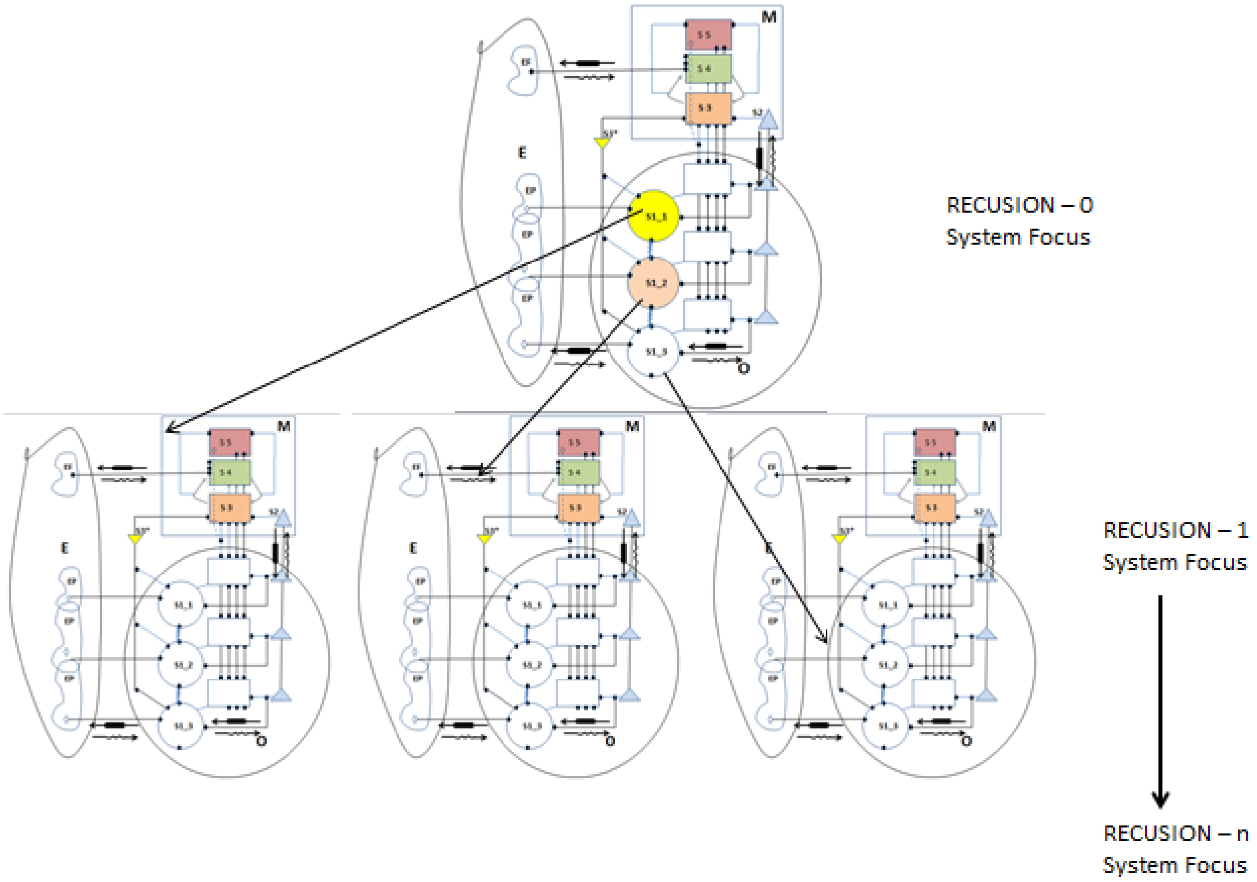
Vertical unfolding complexity implies a decomposition that will ensure fundamental aspects with respect to viability are manageable:

1. **Organization is only viable if it has set of management functions** (Normative, Strategic and Operational Management functions) as stipulated by theory with Management Cybernetics for organizational design.
2. **Any deficiencies in the system such as missing functions**, insufficient capacity or the functions or communication channels (variety engineering), or faulty interaction between functions impair and / or endanger the viability of the organization.
3. **Viability, cohesion** (mission, identity, goals, values) and self organization of **the system depend** on these functions being operating recursively at all levels of the organization.

SYSTEMIC THE WHOLE

The level of recursion level defines within the system in focus WHAT it does and the WHY (purpose), while operating entities define the HOW (System 1 How it interacts with its product and services to its relevant environment. The recursive level characteristics:

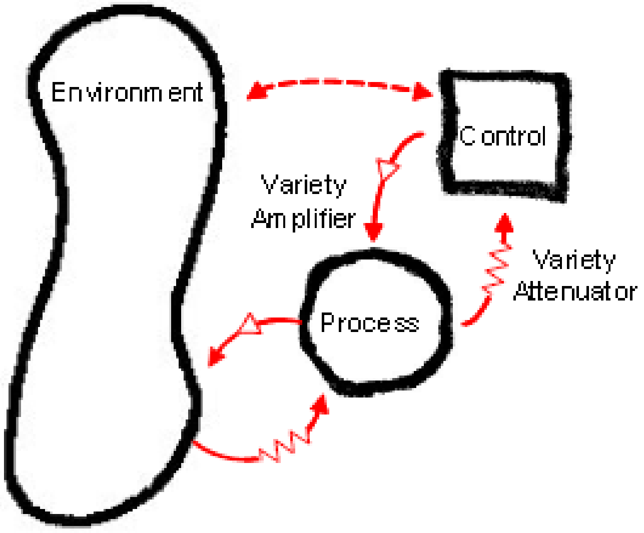
- System in focus : viewpoint.
- Defines identity of what it does and why.
- Level below the 'how' it does it.



A recursive organizational structure any viable system contains, and is contained in, a viable system.

Large systems are assembled from smaller systems. The part must fit into the whole; and the whole must accommodate the part.

Regardless of its size, all viable organizations will consist of and replicated to each recursive level;



- They have an operational part which performs the basic activities,
- A meta-system (control) which is charged with providing the management functions needed by the operational units so that they coheres into a greater whole, and an environment which is in constant interaction with both the operation and the meta-system.

The critical criterion for decomposing complexity is to define levels of recursion that clearly define the WHAT, WHY and HOW. Each level the system engages with different issues and looks at different bits of the environment and different level of recursion will see different consequence of same action. Fundamental criteria for decomposition are:

- Adequate organizational viability diagnosis.
- From a design perspective, ability to ensure effective management functions and their interrelationship are in place to satisfy viability criteria.
- Ability to ensure design adequate **variety attenuators and amplifiers.**

Viable system model (VSM)

Viability is the capacity of a system (organization, state, company, controlling body ect..) to maintain a separate existence and survive via adaptation over time in spite of changes in the environment where its identity will persist through process of learning, adaption and evolution.

The **viable system model (VSM)** is a model of the organisational structure of any autonomous system capable of producing itself. A viable system is any system organised in such a way as to meet the demands of surviving in the changing environment. One of the prime features of systems that survive is that they are adaptable. The VSM expresses a model for a viable system, which is an abstracted Management Cybernetic (regulation theory) description that is applicable to any organisation that is a viable system and capable of autonomy.

In a ‘viable system’ the system and subsystem has following behaviour:

- **Has a purpose**

- **Realizes its tasks**
- **It senses** its internal and external environment
- **It coordinate** its activities with other systems
- **Maintains** a repository of past with respect to key variables
- **It plans** its activities based on its strategy
- **It adapts** to changes to its environment

The model was developed by operations research theorist and cybernetician Stafford Beer in his book Brain of the Firm (1972). Together with Beer's earlier works on cybernetics applied to management, this book effectively founded management cybernetics.

The first thing to note about the cybernetic theory of organizations encapsulated in the VSM is that viable systems are recursive; viable systems contain viable systems that can be modelled using an identical cybernetic description as the higher (and lower) level systems in the containment hierarchy (Beer expresses this property of viable systems as **cybernetic isomorphism**.

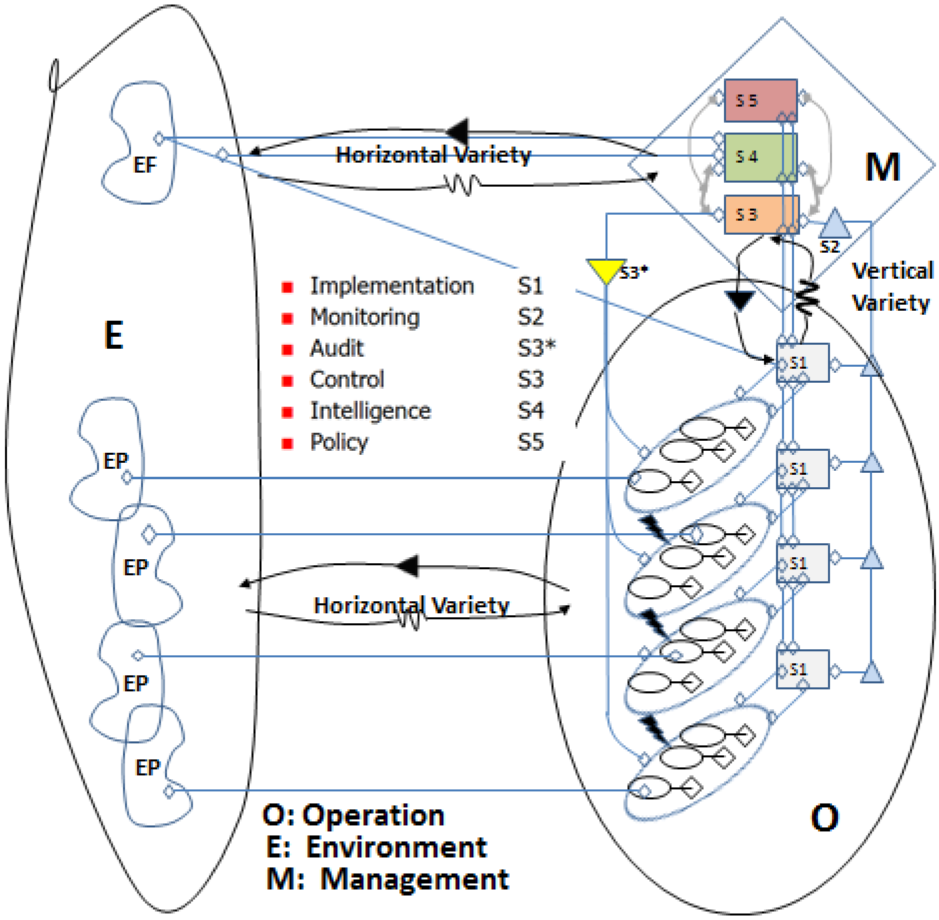
Components of the viable system model

VSM amplifies the science of control in order to have necessary and sufficient conditions for any system to be viable. VSM is based on 5 systems which undertake a systemic role to manage complex systems in order to achieve homeostatic equilibrium of a system under control.

A viable system is composed of five interacting subsystems which may be mapped onto aspects of organizational structure. In broad terms Systems 1–3 are concerned with the 'here and now' (Operational Management) of the organization's operations, System 4 is concerned with the 'there and then' (Strategic Management) – strategical responses to the effects of external, environmental and future demands on the organization. System 5 is concerned with balancing the 'here and now' and the 'there and then' to give policy directives which maintain the organization as a viable entity (Normative Management).

- **System 1** in a viable system contains several **primary activities** responsible for delivery of services and products. Each System 1 primary activity is itself a viable system due to the recursive nature of systems as described above. These are concerned with performing a function that implements at least part of the key transformation of the organization purpose.

- **System 2** represents the information channels and bodies that allow the primary activities in System 1 to communicate between each other and which allow System 3 to monitor and co-ordinate the activities within System 1. Represents the scheduling function of shared resources to be used by System 1, resolution of conflict between System 1.
- **System 3** represents the structures and controls that are put into place to establish the rules, resources, rights and responsibilities of System 1 and to provide an interface with Systems 4/5. Represents the big picture view of the processes inside of System 1, provides goals, expects accountability from System 1 performance (capability, potentiality, efficiency), resource bargaining.
- **System 3*** main function to obtain how System 1 is working ensuring between S1 and S3 is complete, information that does not get to System 3 (accountability) via normal channel: basically audit function (quality audits, work studies, special surveys)
- **System 4** – The bodies that make up System 4 are responsible for looking outwards to the environmental scanning, strategy, planning and innovation and to monitor how the organization needs to adapt to remain viable.
- **System 5** is responsible for policy, identity, ultimate authority decisions within the organization as a whole to balance demands from different parts of the organization and steer the organization as a whole.



In addition to the subsystems that make up the first level of recursion, the environment is represented in the model. The presence of the environment in the model is necessary as the domain of action of the system and without it there is no way in the model to contextualize or ground the internal interactions of the organization.

Furthermore the VSM model contains fundamental aspects around algedonic critical for resilience and provides a critical baseline for adaptation.

- **Algedonic alerts** are alarms and rewards that escalate through the levels of recursion when actual performance fails or exceeds capability
- **Adaptation**
  Interactions between these sub-systems support improved processes and/or self-adaptation to a changing environment:
- **Exception** Management for short-term : System 1 to System 3, System 1 to System 5)
- **Corrective action** (review of System 3* / exception ↔3 / 4, also driver for Process Improvement)

- **Issue tracking** / issue-management (usually triggered by exception mgt, System 2 and/or System 3)
- **Process improvement** (interaction up and down between any System 1..↔..System 5)

Key relationship with VSM

The Viable System model forms the cornerstone for Systemic Context with respect to organization design and continuous diagnosis in a changing environment. Further VSM has critical interrelationship with the following areas:

- **System definitions** and its **variables**
- **Panarchy**: in achieving high level of potential, connectedness (Context) and resilience (algedonic channels) are to design the organization and carry-out continuous diagnosis in a changing environment.
- **System Content**: with respect to system interaction of the elements in order to maximize capability, potentiality, efficiency and profitability. System Content also feeds VSM with 'to-de' organizational requirements that will drive System 3, 2 and 1.
- **Systemic process**: with respect to supporting processes, events, function, supporting systems an organizational units.
- **Systemic Enterprise Architecture**: driver to define EA strategy, goals, objects business processes to support the strategy which eventually drive supporting IT application systems.

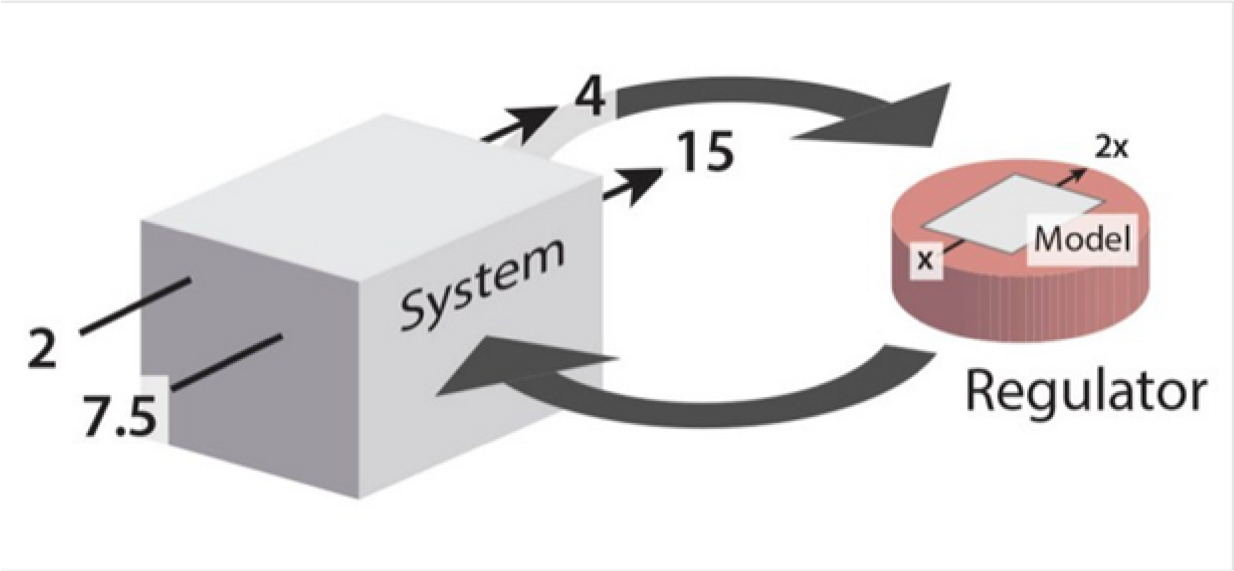
Governance mangement framework

Introduction

The behavior of a system cannot be known just by knowing the elements of which the system is made.

For effective system governance, steering, adaptation and transformation initiatives to be successful it is important to define and understand current system baseline and behavior (actuality). This is fundamental to apply effective leverage and change, minimize damage, cost and risks by applying the right kind of intervention.

The **Conant-Ashby Theorem**, which states that “every good regulator of a system must be a model of that system”. Or in everyday language, to control a system you have to have a model of how it works. This implies a system baseline model (as is).



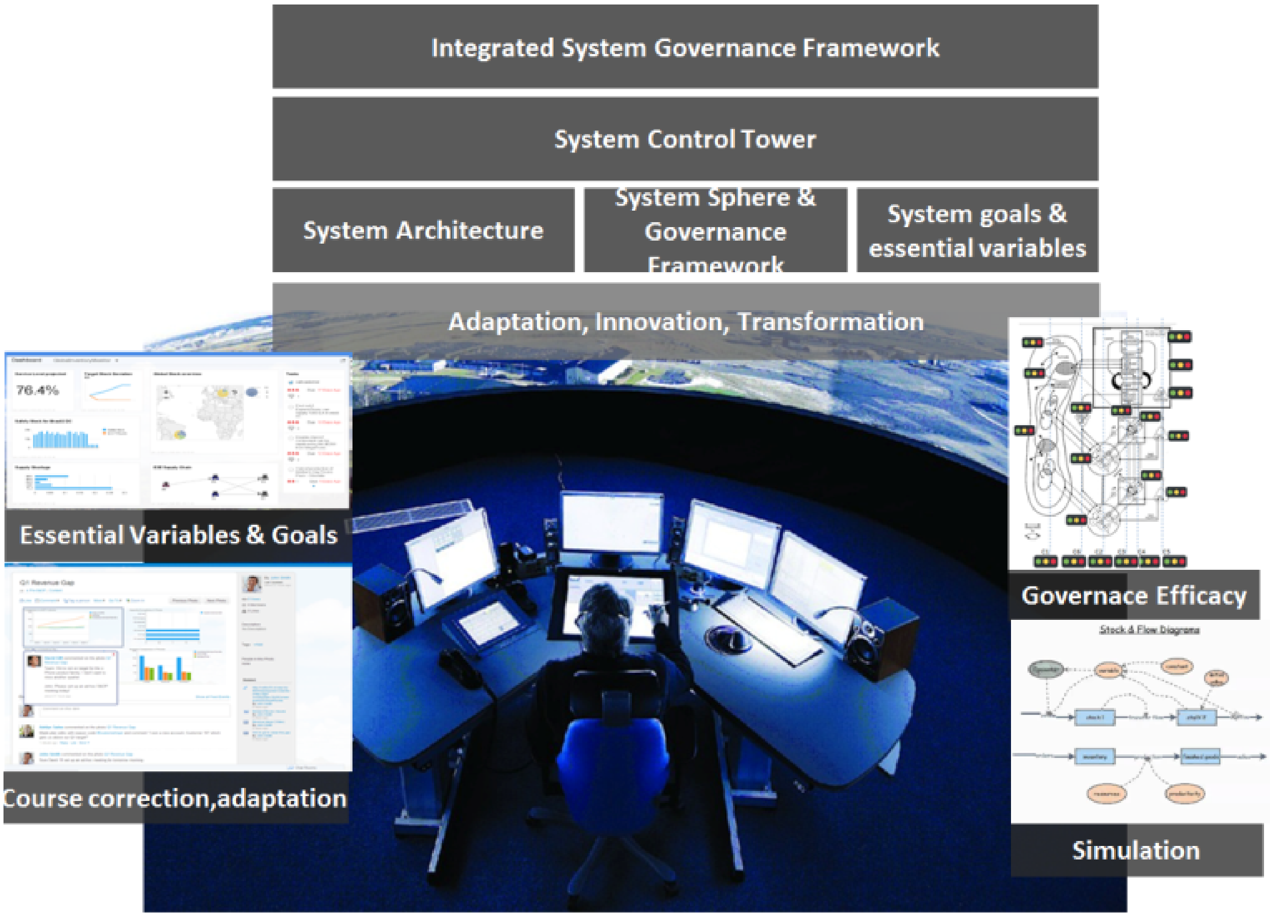
By Analyzing ’ to control a system you have to have a model of how it works’; what does this imply?

It implies always starting with a baseline of the system (System Architecture baseline 0) which describes how the system realizes it purpose based on strategic objective, goals and tactical demand.

The System Architecture blueprint fundamental purpose is to define a model of the system for effective governance which is associated a system cockpit for effective adaptation.

The System architecture is the structure and description of a system/enterprise realizing its purpose. It enables the implementation, understanding, maintenance, repair and further development and adaptation of the system/enterprise to ensure viability, sustainability, profitability and realization of maximum system potential.

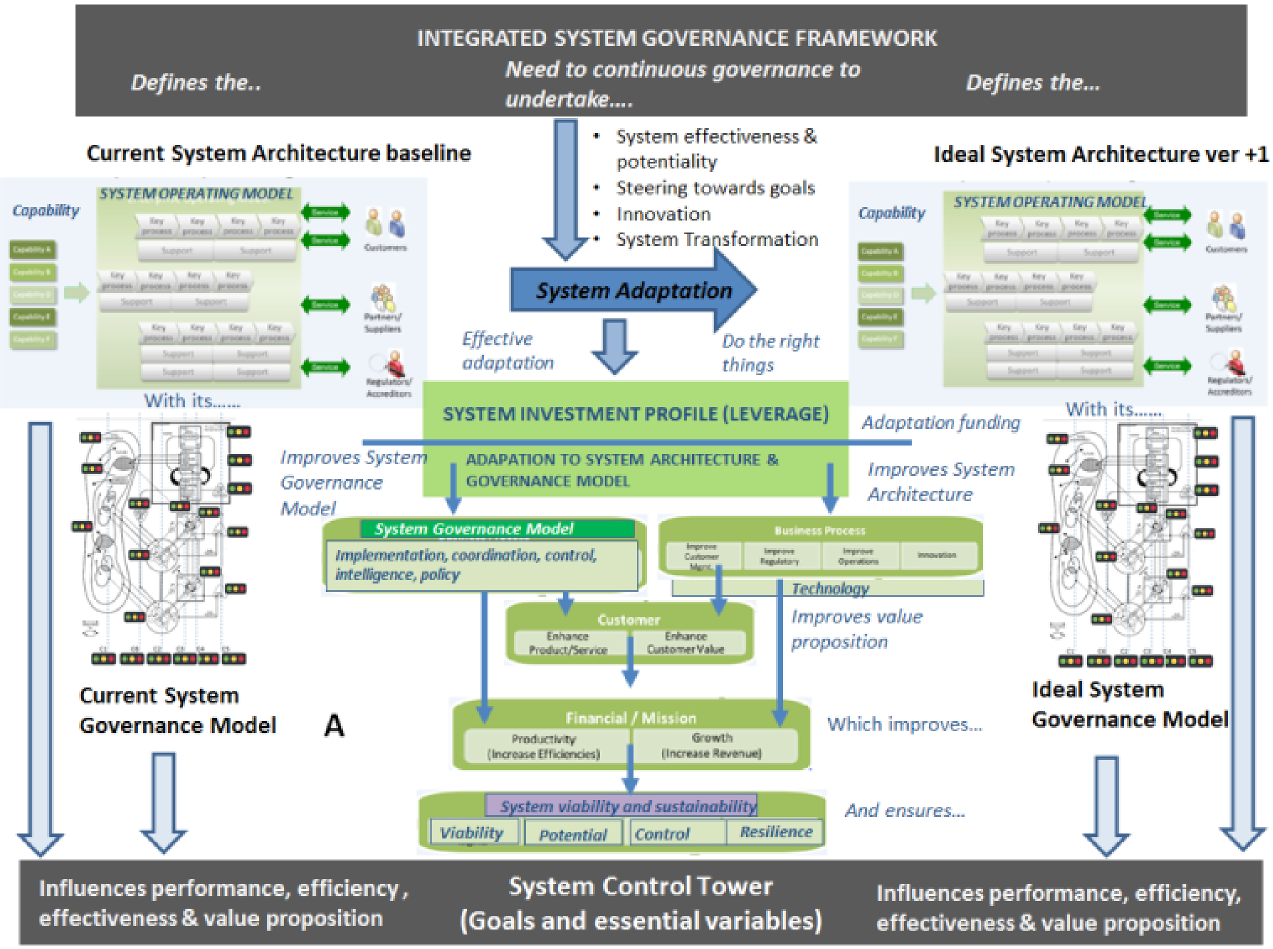
System governance framework consist of defining System Architecture systemic baselines then enables a process of undertaking effective adaptation initiatives to improve system efficiency, **capability, potentiality, potential, viability and resilience**. Effective adaptation entails defining the rights things to do related innovation and transformation considering system state and environmental conditions.


Integrated System Governance Framework
System Control Tower
System Architecture
System Sphere & Governance Framework
System goals & essential variables
Adaptation, Innovation, Transformation
Essential Variables & Goals
Course correction,adaptation
Governace Efficacy
Simulation

System governance is a continuous management for learning and adaptation:

The governance framework consist 3 fundamental pillars:

1. **System Architecture Blueprint**
    - Systems Models
    - Governance model defined as system sphere containing elements for effective system management; Normative mgt, strategic management and operational management
1. **System cockpit**
2. **System steering and adaptation**


INTEGRATED SYSTEM GOVERNANCE FRAMEWORK
Defines the..
Need to continuous governance to undertake....
Defines the...
Current System Architecture baseline
System effectiveness & potentiality
Steering towards goals
Innovation
System Transformation
Ideal System Architecture ver +1
Capability
SYSTEM OPERATING MODEL
System Adaptation
Effective adaptation
Do the right things
With its......
SYSTEM INVESTMENT PROFILE (LEVERAGE)
Adaptation funding
Improves System Governance Model
ADAPATION TO SYSTEM ARCHITECTURE & GOVERNANCE MODEL
Improves System Architecture
System Governance Model
Implementation, coordination, control, intelligence, policy
Business Process
Technology
Customer
Enhance Product/Service
Enhance Customer Value
Improves value proposition
Current System Governance Model
A
Financial / Mission
Productivity (Increase Efficiencies)
Growth (Increase Revenue)
Which improves...
Ideal System Governance Model
System viability and sustainability
Viability
Potential
Control
Resilience
And ensures...
Influences performance, efficiency, effectiveness & value proposition
System Control Tower (Goals and essential variables)
Influences performance, efficiency, effectiveness & value proposition

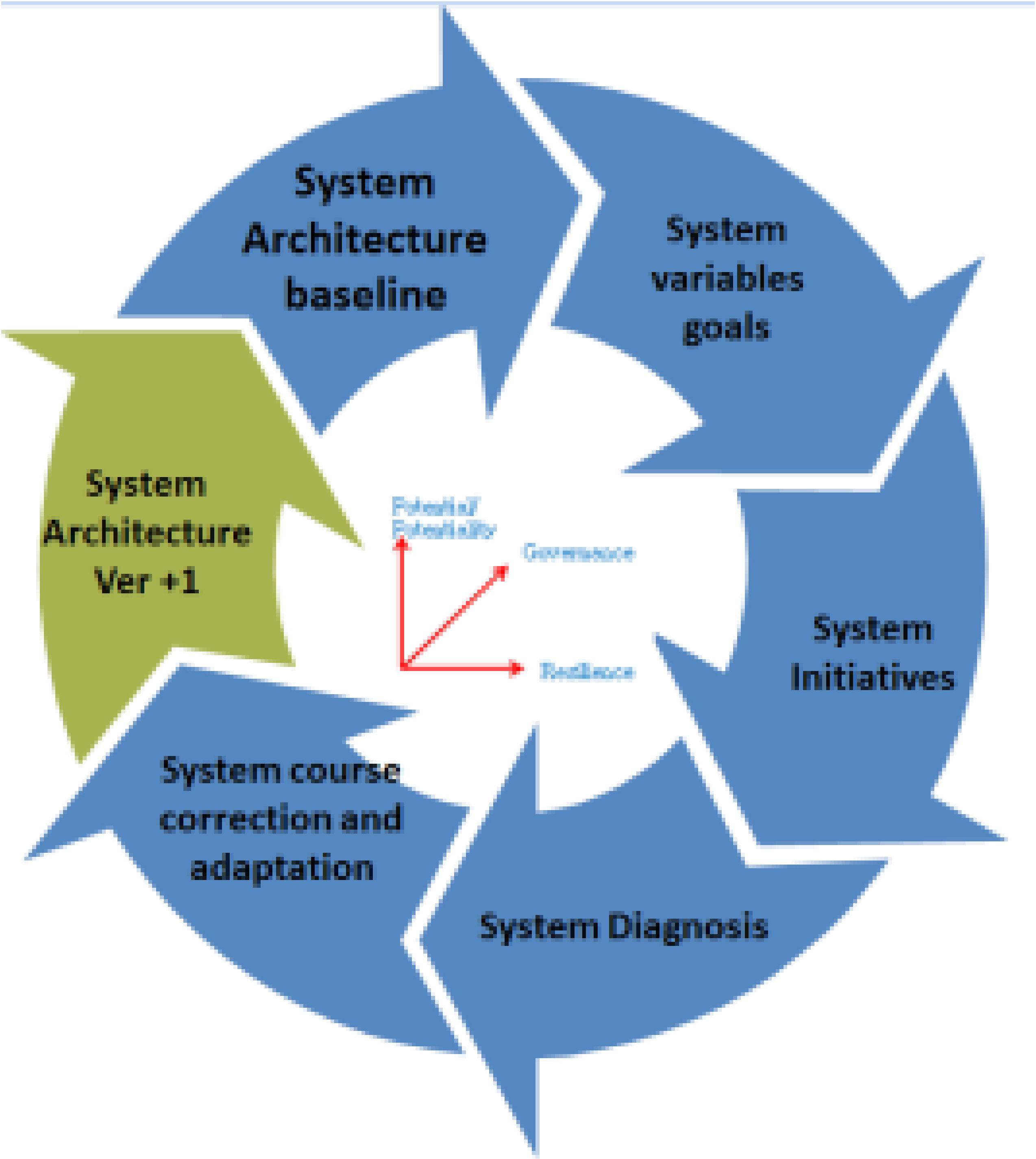
The governance framework defines a system architecture baseline that based on its capability and governance framework generates actual (actuality) system performance, efficiency, effectiveness and value proposition. System actuality also indicates system state and trajectory within resilience stability basin.

System actuality visually within the system cockpit then provides input to the adaption of the system to a new system architecture baseline. This new baseline can be a radical change (system transformation) or incremental change with respect to system adaption (doing the right things):

- Steering towards stated goals or revising stated goals.
- Reviewing.
- Maximizing potential within system purpose and potentiality.
- Innovation and transformation.
- Adapting the governance model.
- Adapting capability model to leverage value proposition with it stated purpose.

This adaptation effort needs to consider investment profile; cost and benefit that will lead to improvements in financial conditions, and provides conditions for improved system viability and sustainability.

The governance framework is a cyclical continuous cycle of learning and adaptation and consists the following:



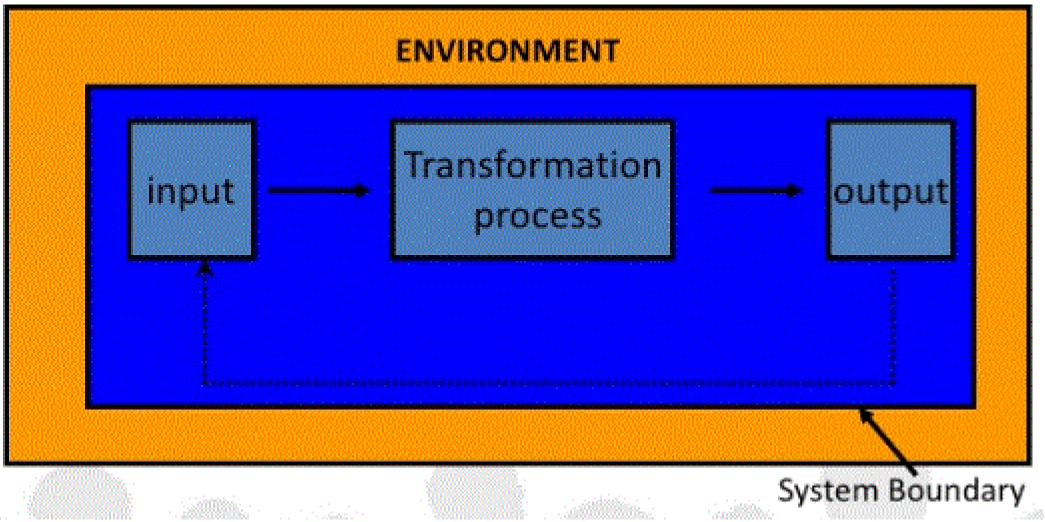
- Defining System Architecture baseline.

- Defining system variables and goals via a system cockpit that associates system state (values) to these variables.
- Validation of system initiatives past, current and future in order to address efficacy, validity and prioritization.
- Diagnosing the system, defining initiatives and realizing initiatives.
- Redefining new System Architecture and realignment of system cockpit.

System architecture blueprint

System definition

According to systems theory, our bodies, our societies, and our universe form an ecology of complex systems and subsystems all of which interact with and mutually influence each other.



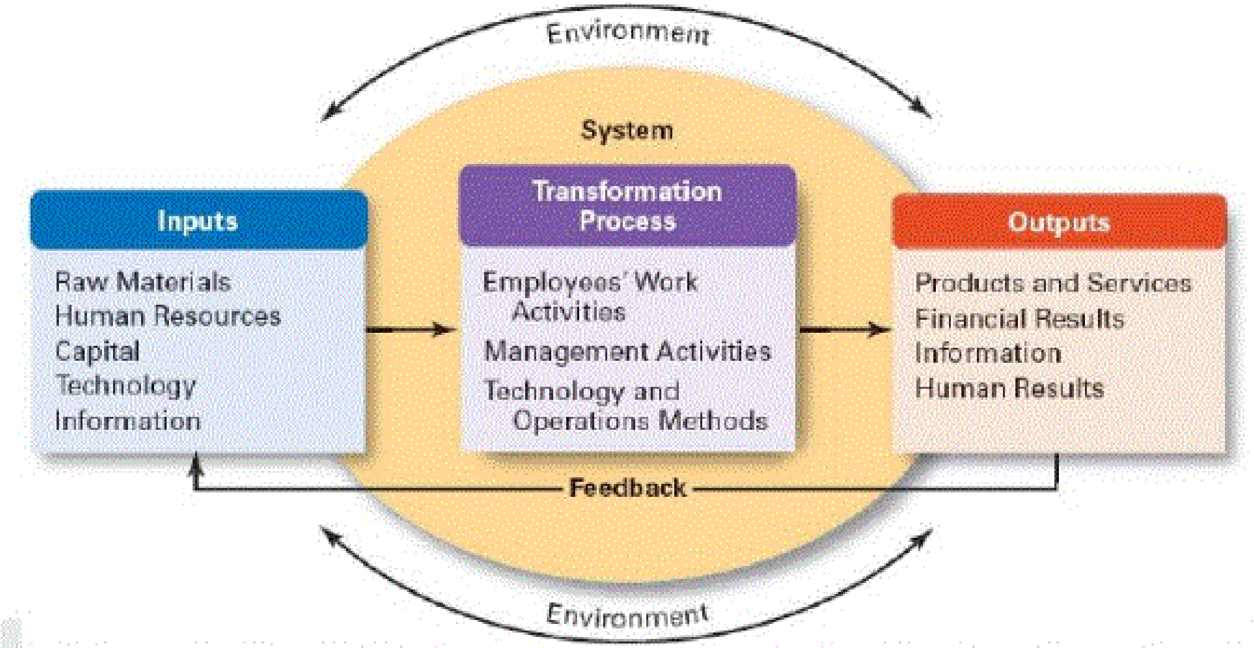
Organization as a system receives input, transforms it through a process for output and operates in an environment made up forces such as economic, regulatory , environmental , competitors ect..

> **"A system is a set of elements or parts that is coherently organized and inter-connected in a pattern or structure that produces a characteristic set of behaviors, often classified as its function or purpose."** (Donella Meadows)

A system consists of a interconnected set of elements (sub-systems) that are coherently organized and work in coordination with each other to achieve a desired goal or overall objectives of the whole. These elements derive their strength by means of association and influence with other elements whereby collective contribution of the system is greater aggregate individual elements: this is known as systemic synergy. Each system has a boundary that separates it from its environment and determine which elements is external and which is external.

Characteristics of a system:

- Integrity or wholeness .
- Adaptive.
- Resilient.
- Evolutionary.
- Goal-seeking.
- Viability: Self-preserving and Self-organizing.



A system must consist of the following:

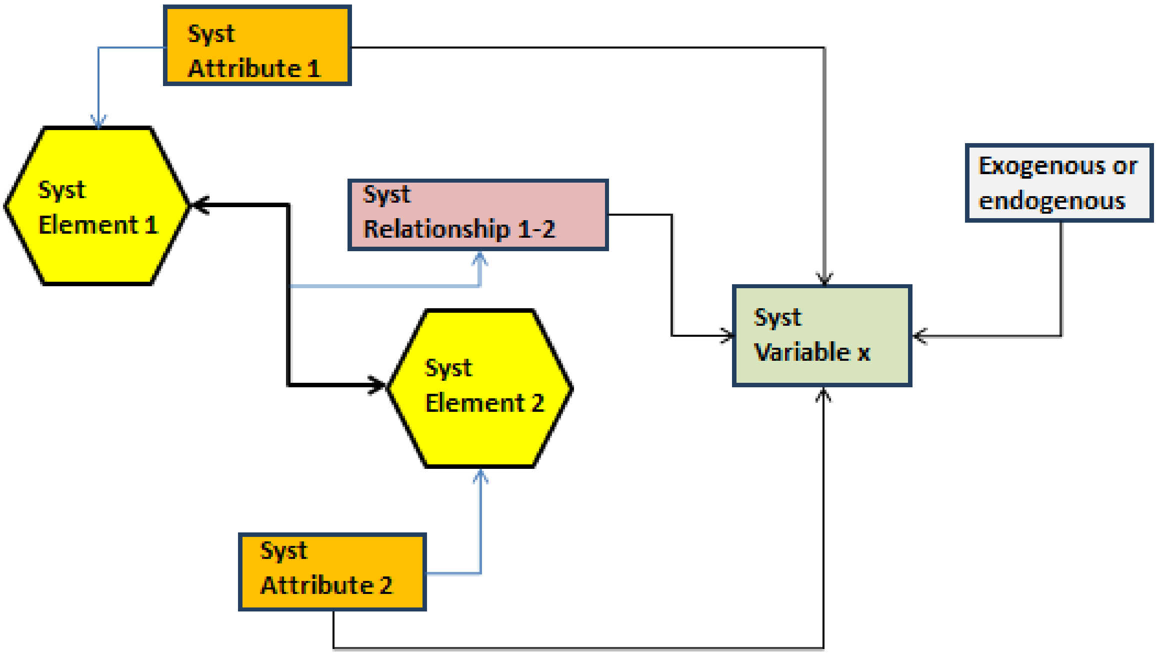
- Function or purpose. Function is used for a **non-human system**, and purpose for a human one. Many systems have both human and non-human elements. Purposes are deduced from behavior, not from rhetoric or stated goals.

- Elements : structure define by parts and compositions.
- Behavior which involves inputs, processing of outputs of materials, energy or information.
- Interconnection: parts have functional and structural relationship between each other, relationships hold the elements together. Many of the interconnections in systems operate through the flow of information. Information holds systems together and plays a great role in how they operate.
- Systems within systems.

Furthermore a system contains attributes (characteristics):

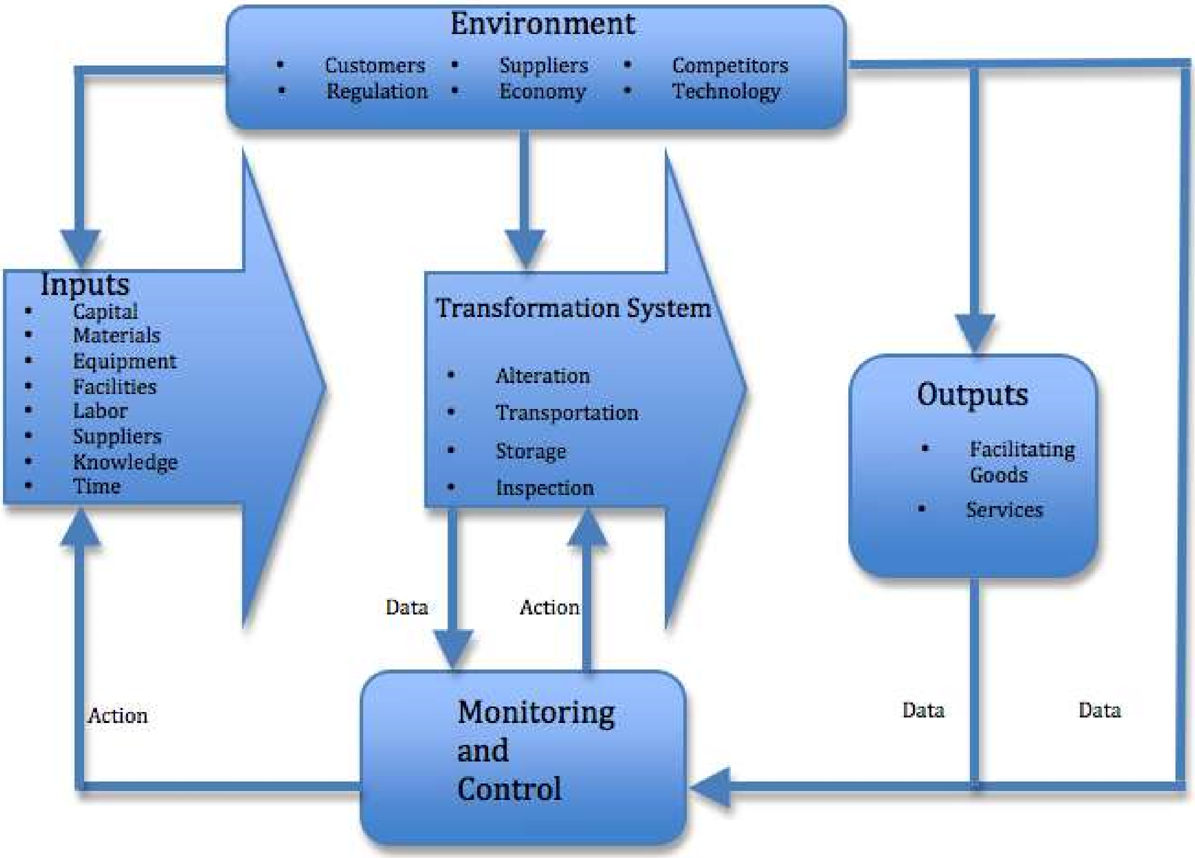
- Attributes of the system elements.
- Attributes of the the relationship (Interconnection) among both elements and attributes.
- Attributes are both fixed and dynamic: dynamic properties of the attributes influence variables.
- These associations are fundamental to understanding cause and effect.

These associations are fundamental to understanding cause and effect.

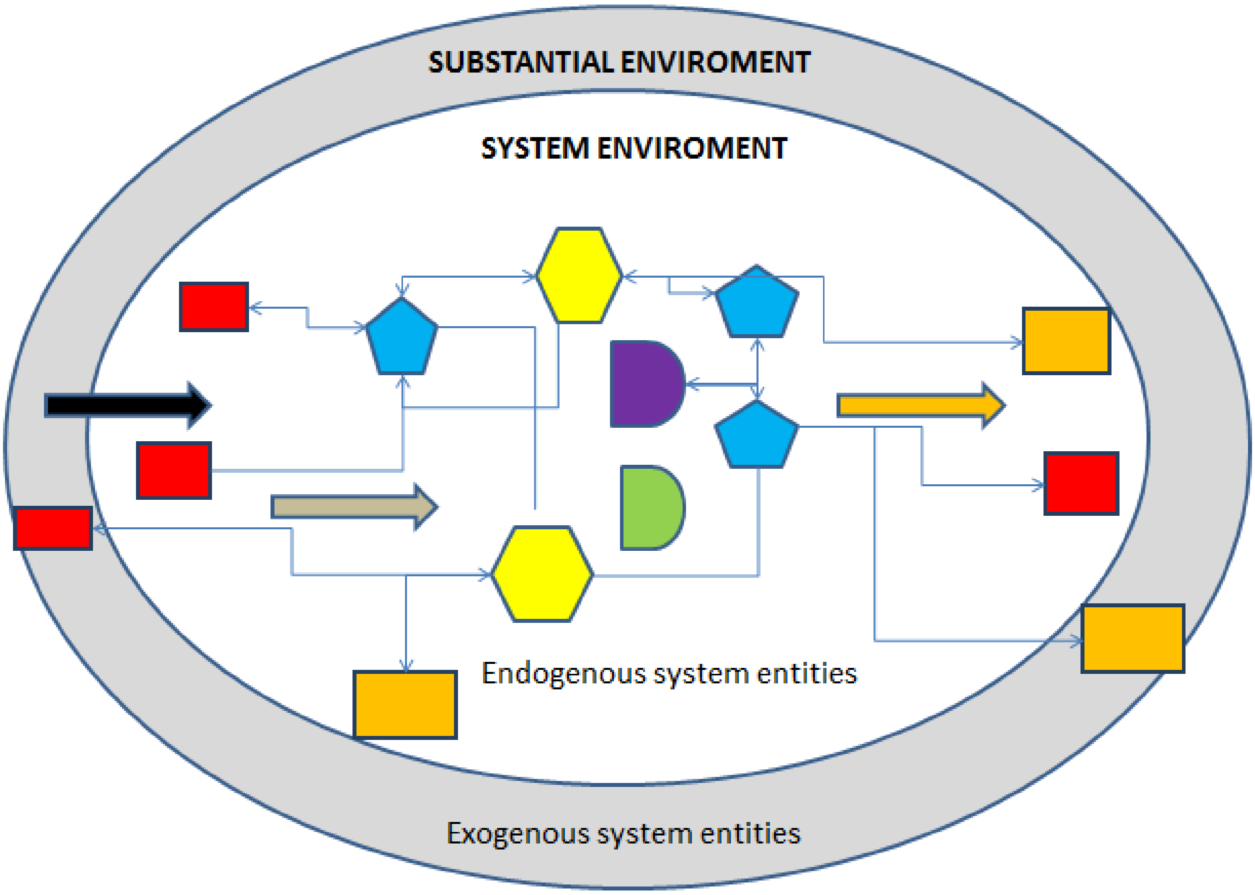


The transformation process of elements which have attributes and relationship are characterized by function called **variables** (quantifiable variables and non-numerical). The system state at any time is the set of values held by the variables at that time.

Fundamental aspect with respect to system is that it transforms input via its transformation systems into output within its know environment within the **context** of monitoring and control.



"Elements are not just physical but also intangible, while relationship / interconnection can be physical flows or information signals. Elements can be part of system (endogenous) or part of the substantiation environment (exogenous)."



A system has three basic elements input, processing and output which result in **system function or purpose**. The other elements include control, feedback, boundaries, environment and interfaces.

Input: Input is what data the system receives to produce a certain output.

- Capital.
- Materials.
- Equipment.
- Facilities.
- Labor.
- Suppliers.
- Knowledge.
- Time.

Output: What goes out from the system after being processed is known as Output.

- Facilitating goods
- Services

Processing: The process involved to transform input into output (Goods or services) is known as Processing.

- Production
- Transportation
- Storage
- Inspection
- Alteration
- Service

Coordination, **Direction and Control:** In order to get the desired results it is essential to monitor and control the input, the transformation and the output of the system.

Feedback: The Output is checked with the desired standards of the output set and the necessary steps are taken for achieving the output as per the desired goals

Boundaries: The boundaries define the limit of the system as well defining the substantial environment (elements outside the boundary of the system).

Environment: The things outside the boundary of the system are known as environment. Change in the environment affects the working of the system.

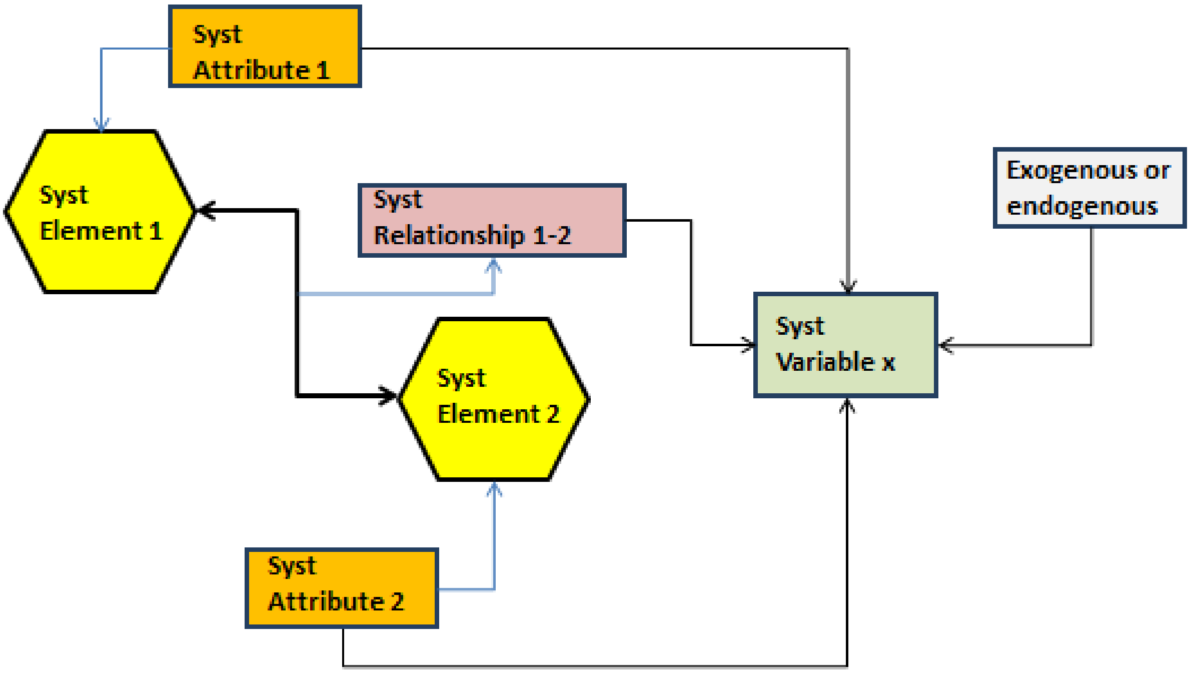
- Customers
- Suppliers
- Competitors
- Regulations
- Economy
- Technology

Interfaces: The interconnections and the interactions between the sub-systems is known as the Interfaces. They may be inputs and outputs of the systems.

The purpose of Systemic transformation is to ensure efficacy (**Adaptability**) of initiatives to enable potential, connectedness and resilience via a process of understating, learning and realization.

Systemic attributes

A system must consist of three kinds of things: Elements, Interconnection and Function or purpose.



Furthermore a system contains key relationships which consist of: Attributes of the elements and relationship (Interconnection) among elements and attributes.

Both attributes and relationship are associated by function called **variables** (quantifiable variables and non-numerical). The system state at any time is the set of values held by the variables at that time.

Important to clearly define attributes that are relevant to variables in order to assign value which define system state and show trajectory, to attributes / characteristics applicable to **system elements**. Attributes particular to system elements main aim is to provide enhanced understanding system behavior.

Systemic Content is about understanding dominant influences (positive and negative) that determine conditions of system elements. Objective of System Dynamics is to define mental models that enable identification of leverage points that will determine ideal system state.

An attribute is an annotation that is assigned to an element and used to store specific systemic transformation data (context, content, process) . This information is stored in the metadata and can be accessed either during systemic transformation analysis process, through to realization and fundamental to the systemic cockpit containing variables. Attributes might change the systemic behaviour of the related element during execution, provide key information about the element systemic behaviour (intended or unintended) , or convey organizational information to transformation agents.]

Attributes that are assigned to elements are fundamental in providing systemic understanding of its behaviors and underlining impact to dominant influences due to the interconnection of attributes.

Examples of systemic attributes to equipment used for systemic transformation:

- Functions performed by machines: Finished product, API etc..
- Bottleneck resource.
- Efficiency
- Output rates
- Shift assignment
- Compatibility product family
- Reliability: includes MTBF (mean time between failures),
- Physical requirements: light, power supply, weight, size, noise, air-conditioning (temperature and humidity) needs

Systemic transformation is to ensure efficacy (Adaptability) of initiatives to enable potential, connectedness and resilience via a process of understating and learning: System content, System Context, System process.

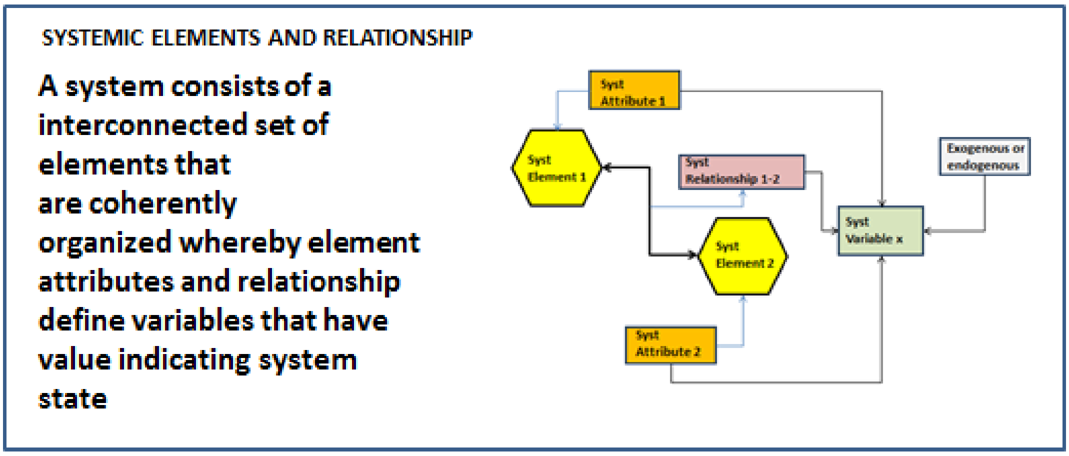
Systemic variables

Variables are the nouns of **Systemic Governance** which are fundamental to the system steering, course correction and adaptation. They are the key forces in a systems story that impact each other and change over time.

A system is a bounded collection of three types of entities:

- System elements
- Relationship of system elements
- Attributes (fixed and dynamic) of elements and relationship

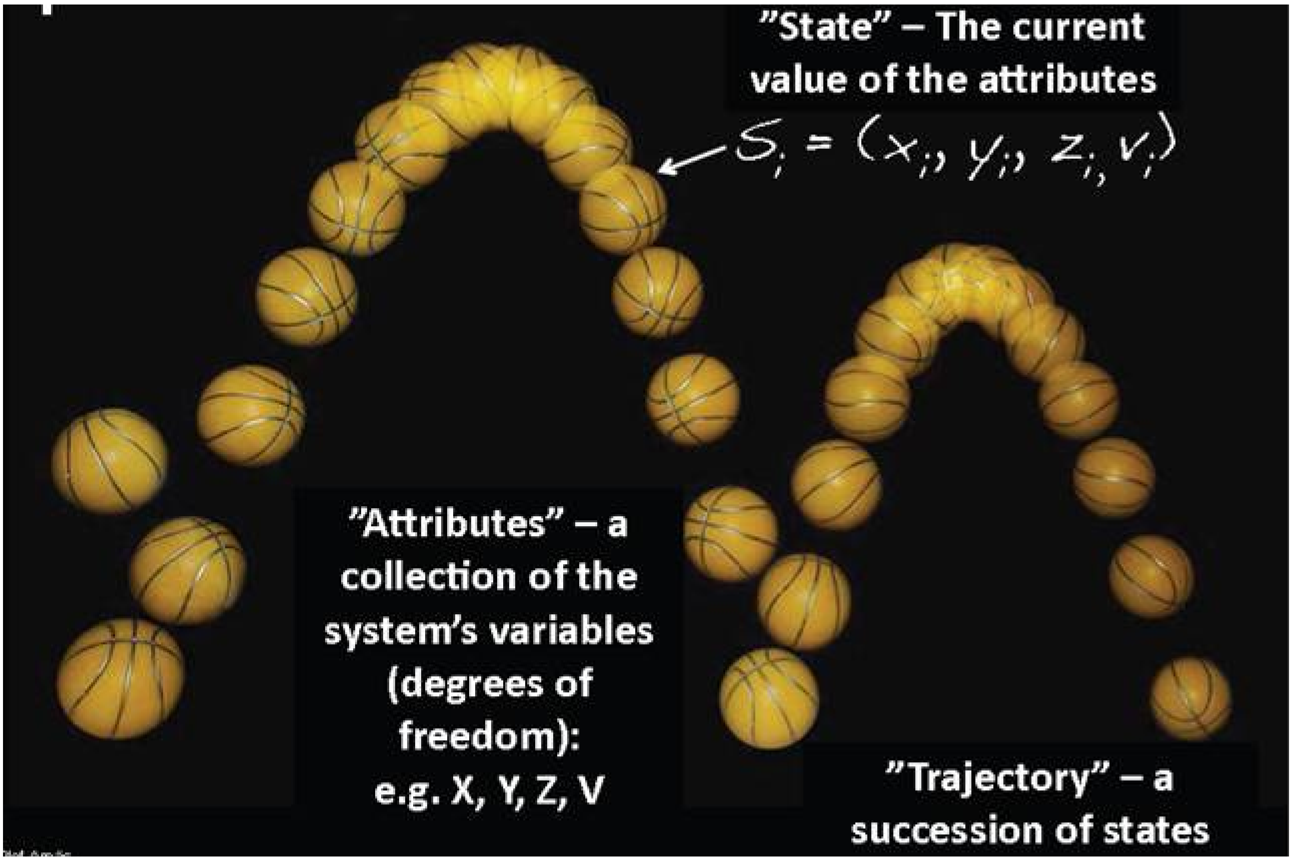
Both attributes and relationship are associated by function called variables (quantifiable variables and non-numerical). The system state at any time is the set of values held by the variables at that time.



SYSTEMIC ELEMENTS AND RELATIONSHIP

A system consists of a interconnected set of elements that are coherently organized whereby element attributes and relationship define variables that have value indicating system state

- Variables can be qualitative.
    - The characteristics being non numeric: example gender, religious affiliation…
- Variables can be quantitative.
    - Information is reported numerically.
- Variables provide system state (current value of the variable attributes).
- Variables have trajectory which represent succession of states over time as a result system behavior.



"State" – The current value of the attributes

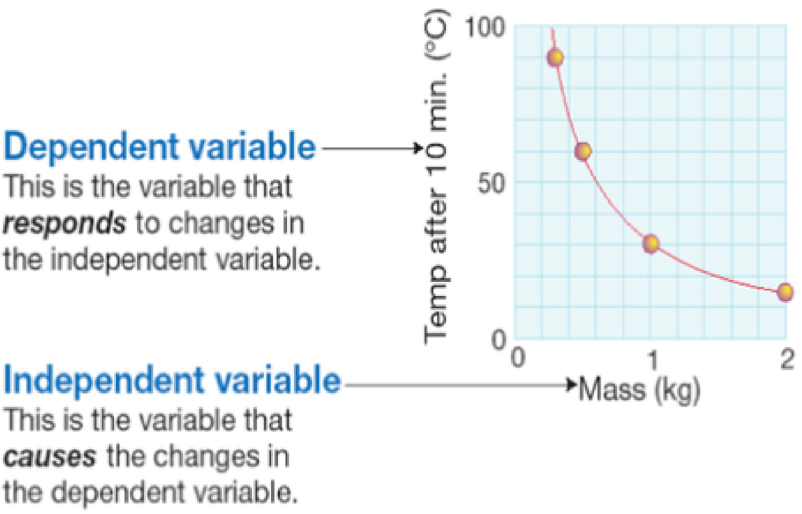
$S_i = (x_i, y_i, z_i, v_i)$

"Attributes" – a collection of the system's variables (degrees of freedom): e.g. X, Y, Z, V

"Trajectory" – a succession of states

Variables have relationship with other variables which can be either defendant or independent variable.

Dependent and Independent Variables



Dependent variable
This is the variable that ***responds*** to changes in the independent variable.

Independent variable
This is the variable that ***causes*** the changes in the dependent variable.

Rule for variables definition:

- Use of nouns or noun phrases.
- Association to what varies over time.
- Endogenous or exogenous variables.
- Variables association to governance model.
- Variables association to:
    - System elements.
    - System relationship between elements.
- Variable categories that provide clear understating systemic behavior and its purpose.
    - Variables related to goals:
        - Desired level of …..(eg: market penetration, throughput).
    - Variables related systemic thinking, perceptions, feeling.
        - Level of commitment to achieve…(eg: product quality).
        - Level of alignment around organizational.(eg: mission).
        - Perceived level of...(example quality).
        - Perceived level of clarity…(organizational goals, mission, policy).
    - Variables related to demand.
        - Pressure to...
        - Need to…
        - Demand to…
        - Gap between … and…
    - Variables related to supply.
        - Capacity for..(eg: customer demand).
        - Ability to…(eg: supply as per agreed service level).
        - Available transformation resources…(eg: capacity, effective capacity).
        - Investment in… (eg: service resource, training).

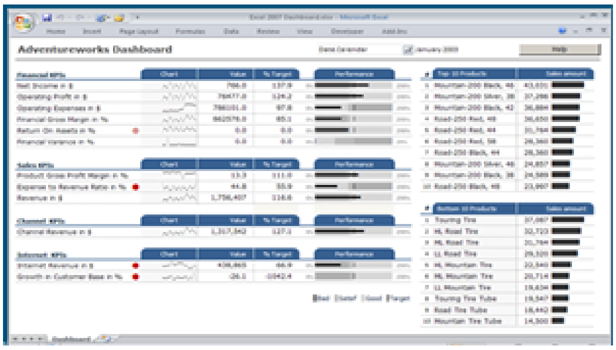
- Variables related to results actual level of performance.
    - Profitability, revenue, debtors, creditors, cycles time , costs, market share.
    - Quality of…(eg: related to errors, product).

From a systemic governance perspective, variables are fundamental in supporting a system control tower that allow for effective governance , steering and adaptation.

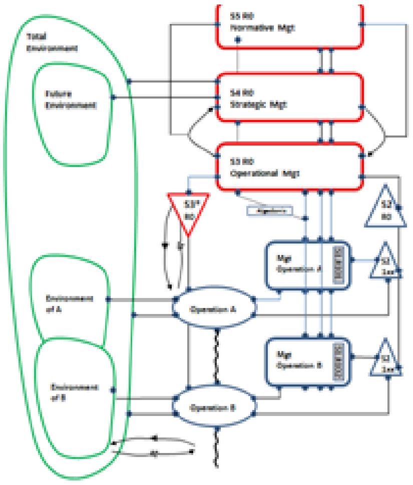
Systemic control tower

The control of Organizational Systems can never be a matter of one-time decision-making, but rather it requires perpetual cycles of acts and effects on which over time any effect becomes the reason for another. A System Control Tower (SCT) is a centralized function that helps companies / system orchestrate (effective adaptation) in order to ensure that it is able to achieve its goals and maintain its identity despite changes taking place in the environment. The goal is to enable advanced visibility and standardized, real-time analytics from a single source of truth to provide an unobstructed view of where to take action and apply resources.

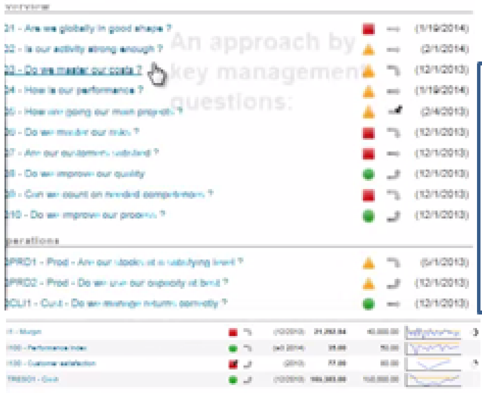
Organizational systems require a system control tower in order to steer the system towards its indented goals (set course) considering environmental conditions in other to allow effective course correction and adaptation. The cockpit must provide for the ability to define the system, where it’s want to go, its current state, and its efficacy in achieving its objective.



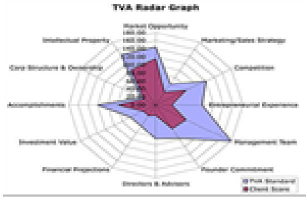
System Performance Versus Targets



Model of the organization



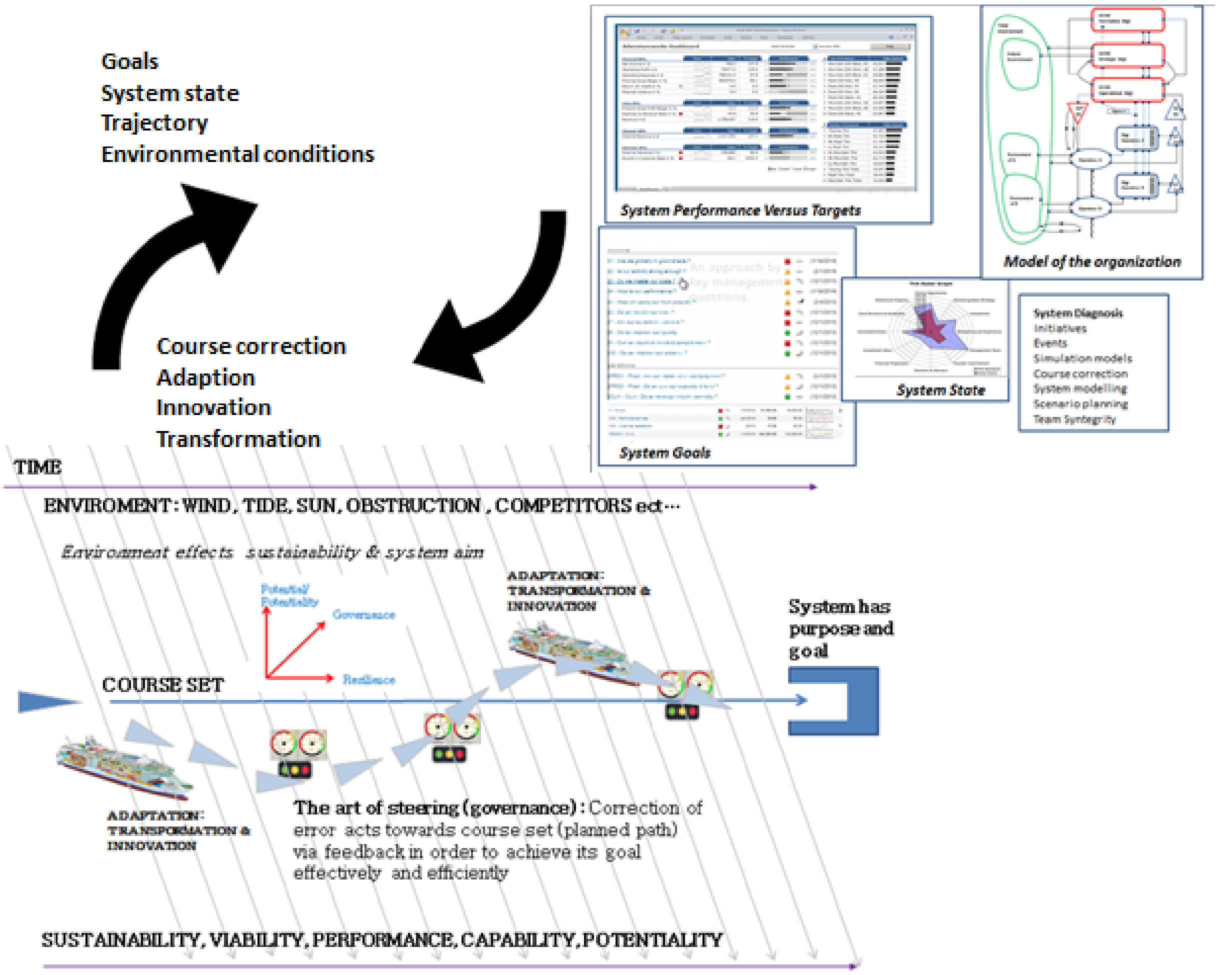
System Goals



System State

System Diagnosis
Initiatives
Events
Simulation models
Course correction
System modelling
Scenario planning
Team Syntegrity

The system control tower in order to be effective should have same characteristics of a air traffic control tower which show system in relation to its environment plus a flight cockpit in order to steer the system based on input from within the cockpit and external conditions.


Goals
System state
Trajectory
Environmental conditions
Course correction
Adaption
Innovation
Transformation
System Performance Versus Targets
Model of the organization
System Goals
System State
System Diagnosis
Initiatives
Events
Simulation models
Course correction
System modelling
Scenario planning
Team Syntegrity
TIME
ENVIROMENT: WIND, TIDE, SUN, OBSTRUCTION, COMPETITORS ect…
Environment effects sustainability & system aim
Potential/ Potentiality
Governance
Resilience
ADAPTATION: TRANSFORMATION & INNOVATION
System has purpose and goal
COURSE SET
ADAPTATION: TRANSFORMATION & INNOVATION
The art of steering (governance): Correction of error acts towards course set (planned path) via feedback in order to achieve its goal effectively and efficiently
SUSTAINABILITY, VIABILITY, PERFORMANCE, CAPABILITY, POTENTIALITY

[SCT] The Control Tower is fundamental in order to carry-out effective system governance / steering in to provide important data that enables, learning, course correction and adaptation; innovation and transformation in order to ensure long-term sustainability and viability. In order to gain the expected benefits, it is necessary that the system/organization adapts and transform itself within the ecosystem in which it operates.

A system control tower is more than just an Information Technology project. Implementing a SCT is much more than that in that is must aid effective governance (based on Cybernetics principles) and adaptation to guarantee sustainability and viability by doing the right things.

Key essential elements of a SCT:

- High quality external information feeds (exogeneos variables) and major events.
- **High quality internal data** (variables and their relationship). Critical essential variables associated with goal states stability designed within **variety engineering.**
- Understanding emergence of variables state that are associated to:

    - System elements and their attributes.
    - System elements relationship and their attributes.
    - Organizational structure relationship and environment association (country, market).
    - Governance model association to specific operational functions.
- Real-time Key Performance Indicators (KPIs).
- Real-time and predictive alerts based on deviation critical variables stated goal threshold.
- Processes and automated workflows to trigger immediate response.
- Real-time analytics.
- Decision support capability by providing a space for simulation models.

The purpose of the System Control Tower is to create and share valuable information in a visual manner in order to undertake effective (governance) decisions in order to ensure that the system set-course is maintained and if needed adapted. In order to satisfy the needs of system governance the cockpit should consist of:

System definition

This space covers the know definition of the system paradigm and its set-course:

- System purpose.
- System elements, relationship and properties.
- System governance model (VSM).
- System Goals.
- System Variables and association of goals to variables.
- Process Management.
- Enterprise Architecture.

System monitoring

This shows current status of the system critical essential variables which are displayed graphically and numerically. Usage of color (red, yellow, red) to show in which difficulties are encountered (versus planned goals) which require vigilance. Critical variables to show relationship to initiates and event to facilitate learning and decision making and trigger any further review on efficacy of the initiative.

Furthermore critical alerts should be given based on critical variable state. Each of the variables must have related history showing trajectory.

This space covers monitoring variables and reacting to alarms alerts

1. Inserting events (2) and relationship of events.
2. Status of goals, efficacy of goals (the right goals).
3. Actual variables state and trajectory.
4. Alarms algedonic signals.
5. Governance model efficacy: key indicators with respect to governance model.
6. Real time analytics.

System course correction

Based on system actual state versus set course initiatives are carried to adjust to set-course that influence efficacy and efficiency of current system paradigm and adaptation to future paradigm with respect to decision support:

1. Course correction statement (3) to manage coordination action.
2. Initiative mgt: what type, status (planned, actual, wip) date, cost, benefit.
3. Course correction action: when where benefits.
4. Realization System Adaptation Specification: the WHAT the HOW.
5. Modelling space: simulation model, casual loop.
6. Innovation management space.
7. Transformation management space.
8. Team initiatives.

System related stuff

In order to use System Cockpit related functionality is needed such as:

- User admin.
- Calendar for events.
- Internal social media for discussion, comments.
- Banner of things happening, internally and externally.

- Project mgt space to show initiative status with respect to realization.

Key characteristics of the cockpit.

In order to be effective the cockpit should allow visualization and data that specific to system viewpoint: therefore cockpit must show spaces relevant to area of governance.

Must be able to roll-up aggregate data to highest level for global level at the same dime disaggregate to its level of its governance.

It must provide smart graphical and tabular data to clearly show system state and areas of intervention. Graphics to have dynamic data relationship: by scrolling over a graph or data object must allow for additional data pop-up.

The cockpit must clearly show key performance of essential variables and identify negative trends. The cockpit must allow for the monitoring of all types of incidents, situations, and changes that might lead to operational interruption or major swings. They know when an interruption has occurred and help coordinate a response.

Data is obtained from various sources about occurrences around the world. So much information is gathered in that the control towers need to use analytics to sort through these to define which ones are important to the system in relation to system in focus. It is important to know which occurrence needs to be attended to and which can be ignored.

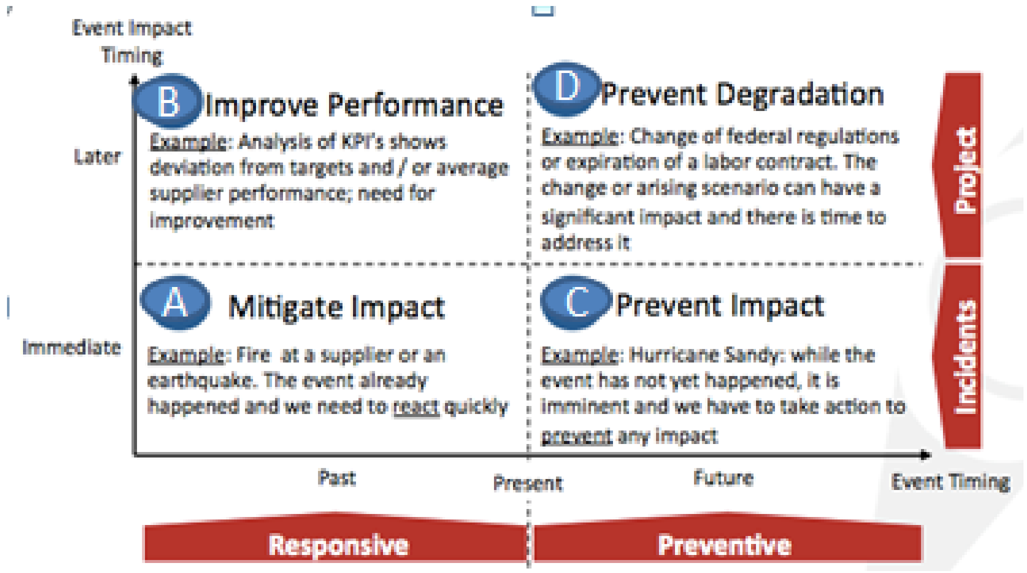
The System cockpit must be managed by team in order to manage data and ensure that only data that is relevant is associated with the cockpit.

Notes:

- **Initiative**: system initiative to do something.
    - Type of initiative: course correction, alarm action, innovation, transformation, change mgt, training. Areas of the system influenced: system elements, VSM governance framework.
- **Events**: events that may influence goals and variables. Event origin: internal or external: Event type : course correction, innovation, transformation: relationship of event/influences to variable: Date, cost, expected benefit.
- **Course correction statement**: Identification of course correction: type (responsive, preventive) , person or team, brief statement , areas of the system (elements and VSM) , variables, statement of work (effort).

- The Control cockpit is not just a tool but requires a team in place that is continuously understanding system behavior, learning from past actions, process improvement, performance improvements, innovation agents, transformation agents.
- **The cockpit must allow of both responsive and preventative course correction**. Key alarms require immediate response; while performance aspects such as capability and potentiality can be of a less urgency. Once problems occur in the system an analysis needs to be made of the source of the problem. Often this can involve analysis of the data in the systems to understand reason for the deficiency or what went wrong that caused the problem. The cockpit key aims should allow for continuous learning that will enable responsive and preventative action.
- Diagnosis framework:
    - To better understand and manage steering and adaptation which can either be responsive based on system state of the past an present or preventative based on potential future conditions, steering correction or adaptation which require suitable response with the relevant urgency based on two fundamental criteria:

      Has the change, situation, or incident that can cause an interruption already occurred?
      How imminent is the impact and how fast do we need to respond?


Event Impact Timing
Later
Immediate
B Improve Performance
Example: Analysis of KPI's shows deviation from targets and / or average supplier performance; need for improvement
D Prevent Degradation
Example: Change of federal regulations or expiration of a labor contract. The change or arising scenario can have a significant impact and there is time to address it
A Mitigate Impact
Example: Fire at a supplier or an earthquake. The event already happened and we need to react quickly
C Prevent Impact
Example: Hurricane Sandy: while the event has not yet happened, it is imminent and we have to take action to prevent any impact
Project
Incidents
Past
Present
Future
Event Timing
Responsive
Preventive

- Responsive (past):

  - **A: Mitigate System Impact – Immediate:**

    Serious failure has occurred and quick reaction is required. The cockpit should provide visual alarms in order to allow rapid reaction. The typical example is an explosion or fire at a supplier, an earthquake or a tornado. Root cause analysis and corrective actions are not needed in these cases. The main goal is to mitigate the impact. Preparedness and speed are key.

  - **B: Improve System performance – later:**
    Related to initiatives to improve performance whereby critical variables/KPI has shown performance below stated goals. Initiatives include improvement in performance, efficiency, effectiveness, capability and potentiality.

    The goal is to improve performance and prevent an interruption. The Control Tower watches performance indicators (KPI's) and highlights deteriorating KPI's as they pose higher risks. Root cause analysis and corrective actions are key elements in the resolution process.

- Preventative (future) Crumbling paradigm:

  - **C: Prevent System Impact : Immediate:**
    While event has not yet happened, it is imminent (high level of certainty) requiring relevant action to minimize or prevent impact. A typical example is a supplier in financial distress or experiencing major quality issues. Here root cause analysis and corrective actions are not important. The main goal now is to prevent the impact; preparedness and speed are again the key.

  - **D: Prevent System Degradation Later:**
    This kind of initiative considers environmental conditions effect on the system that could lead to significant impact on the system sustainability and viability requiring adaptation such as innovation and transformation. The goal is to prevent degradation of the system requiring project-like setup and time to understand the issue. (Root cause analysis is necessary to develop the best "response", scenario planning, causal loop diagram, governance simulation).

System steering and adaptation

Introduction

Change is inevitable for any system (Enterprise, government) in its life-cycle regardless of how successful it has been in the past.

Change is driven within organization of the system itself: its structure, governance, resources, its business model (merges and acquisition , expansion to new markets). Change is also driven by external factors such as market competition, disruptive technology, new goverment regulations, demographics and environmental factors.

When undertaking change/adaptation many factors need to be considered:

- **System complexity**: system are multi faceted and are interconnected with the environment and markets, its operation entities and its management in multitudinous ways.
- **Adaptation effect structure and process** (resilience threshold), identity and feedback
  - Business process, internal processes, technological infrastructure.
  - Structure related relationship with the environment (geographical).
- **Change impact different levels** / layers such the business model (how business generates revenue, how it ensures sustainability) the organizational model (control, organization, leadership, attenuation) to maximize potential and control resilience.
- **Technological changes to leverage potential**, management control and enable new business models These changes require continuous adaptation following cycle with feedback consisting of:
  - Exploration of current systemic situation (shared understating) by building a prototype that capture its essence in terms of potential, viability and resilience.
  - Diagnose (identify leverage) and design new structure (future structure) , policies, processes, technological leverage and validate by simulation to test systemic prototype.
  - Realize the new design (leverage) using prototype as a guide (model of the system).
  - Monitor via systemic operation room (control tower) in order to have continuous feedback (feedback loop to exploration, design) needed to validate prototype and realized initiative.

Innovation and transformation

While system steering is mainly concerned with course correction of the system towards set-course within defined system structure (elements, goals, properties, governance, relationship, sub-system) in order to achieve stated goals, maximize efficiency, effectiveness, capability and potentiality.

While adaptation refers to adjustments in systems in response to actual or expected stimuli and their effects or impacts with respect to dynamic properties of a viable and sustainable system (potential , connectedness and resilience) . It refers to changes in processes, practices, and structures as a response to environmental change.

Systemic adaptation is about ‘doing the right things considering system state and environmental conditions:

- Steering known system towards set-course.
- Transformation – totally new paradigm: involving a terminus or crumbling paradigm. Totally new system definition and governance model.
- Innovation – step change in product or service offering within established system definition and governance model.

Where adaptation is ineffective it can be catastrophic: Some example of poor adaptation where organization/systems disappeared or are in permanent decline:

- Yahoo
- Nokia
- Texas Instruments
- Kodak
- Polaroid
- Compaq
- NEC
- Amiga
- Palm , Sony Erikson ect….
- Catastrophe amongst major Banks surviving due to extensive public intervention
- Permanent decline of the of the Greek and Italian economic system within the EU

The 110 biggest product failures of all times

Each of the above can be attributed to ether failing to understand that their the system set-course was defined within a crumbling paradigm (Kodak) or its poort innovation approach (Nokia insistence with Windows mobile killed the company).

Failing to do the right things impacts system viability due to a decline in system sustainability related to its potential and resilience. Adaptation failure are also caused by poor governance, inability to steer the system right direction considering system course set and environmental conditions.

Transformation is the process of starting or and ending a paradigm involves a terminus.

Start implies a new paradigm that may result in the end of existing paradigm or triggering a crumbling paradigm. Typical example digital versus film (which marked the end Kodak), or the shipping container, email. Within a system/company, it implies the complete redefinition of its core value proposition – change on system broad model, a pattern, a framework, way of thinking for understanding reality, behavior, and the rules within the system boundaries.

Innovation is the process of evolutionary step-changes in a product or service offering within defined system paradigm. Think about incremental releases (versions) of software – each designed to build from the previous, but adding various improvements in design and ability or new auto car release within existing series. Innovation operates within existing system within know system elements and their functional relationship and environmental conditions and existing governance model.

Adaptation activities span five general components: observation; assessment of system impacts and vulnerability; planning; implementation; and monitoring and evaluation of adaptation actions.

Observation

At the outset of any adaptation initiative, observation and monitoring via system cockpit of key goals and essential variables is important to understand system behavior that will lead to adaptation that will then enable improved understanding, modeling and prediction of the system change impacts. The system cockpit in order to be effective should provide:

- Key variables , their historical progression, association of key events
- Properties/attributes of key variables and association with other variable and system elements in order to understand dynamic progression
- Variables association to goals and target

- Association of past event to variables
- Alerts

Assessment

Adaptation assessment refers to the practice of identifying options to adapt system to change, and evaluating them in terms of criteria such as benefits, costs, effectiveness, efficiency and feasibility

Planning

Defining the key adaptation initiative and their priorities, expected benefits, areas of the system , cost , change management effort, timing , governance model to ensure effective application and monitoring of the initiative.

Implementation

Implementation entails the realization of adaptation initiatives. Entails creating a realization specification that clearly defines the WHAT and the HOW to effectively realize the adaptation initiative:

- The type of adaptation: steering changes, innovation or transformation
- The actual initiative
- Impacting elements of the system/sub system (Enterprise IT architecture)
- Cost and benefit
- Risk analysis
- Time- line
- Supporting governance model
- Impacting variables
- Change management , training
- Monitoring criteria to determine efficacy of the initiative
- Timing
- Status

Monitoring and evaluation

Given the complexity of the system initiative, it is essential that adaptation initiative is designed that it includes feedback, its essential variables, goal states to enable effective monitoring and evaluation: fundamental for continuous learning and understanding efficacy and possible emergence of unintended consequences. The implementation of the adaptation initiative needs to be regularly monitored, evaluated and revised, both in terms of the validity of the underlying assumptions and the appropriateness of initiative intervention including their effectiveness, efficiency and overall utility. The monitoring and evaluation framework must be developed to ensure clearly formulated goals, objectives and output measures as well as the availability of good quality data obtained via a system cockpit.

Team synergy – sinergia of what to what

'exploiting collective intelligence and cognitive diversity'

Adaptation, innovation and transformation are extremely difficult to manage and realize; 'doing the rights things'. This difficulty is mainly associated with failing to understand complexity and the variety propagated by systems and too much reliance on single managers or super CEO.

Organization systems face extremely high internal and external complexity that determine the survival, efficacy, performance and resilience of a system in their specific competitive environments. In order to cope with complexity, system according to Ross. W. Ashby they can only do so if the directive (governance) and regulatory mechanism that are in place are able to cope complexity they need to manage; the variety of management (governors) is at least equal to the variety caused by the organization and its environment. This can only be achieved if the entire knowledge, intelligence and cognitive diversity that is available in the organization is combined and exploited to leverage, innovate and transform the system. Many organization consist accumulation managers, engineers and specialist collectively via an efficient protocol which is able to provide critical direction.

Typical example of high expectation; expecting from single person to execute major transformation relates to HP: http://www.forbes.com/sites/frederickallen/2012/03/05/why-great-innovations-fail-its-their-ecosystem/#a2e4aa6b5336. HP Carly Fiorina may be an excellent CEO but it does not imply the CEO has the ability to carry-out major transformation and successfully introduce industry paradigm. Same can be said about Steve Jobs: very successful with iPhone, tablets ect..; but it does not imply that Steve Jobs at Nokia would have made a difference.

Nokia (https://hbr.org/2011/02/the-real-cause-of-nokias-crisi.html) further example transformation failure: in this case the main issue was not related to innovation but more related to fact that their whole governance model was based on a crumbling technological paradigm impacting their resilience. They failed to understand that innovation in a crumbling paradigm can only lead to failures.

Why innovation fails?

http://fortune.com/2014/10/07/innovation-failure/

"If you had to guess, what percentage of ideas for ground-breaking new products or services would you say are marketplace flops, or just never see the light of day? 50%? 80%? According to Mark Payne, it's closer to 90%"

Why transformation fails?

The reported failure rate of large-scale change programs has hovered around 70 percent over many years.

http://www.mckinsey.com/business-functions/mckinsey-recovery-and-transformation-services/our-insights/transformation-with-a-capital-t?cid=soc-web

Accenture: According to Gartner, "almost 90% of transformation projects miss their mark."

According to research by McKinsey & Company, about 70% of all changes in all organizations fail.

After almost two decades of intense change from corporate reorganizations, new software systems such as ERP , and quality-improvement projects (six sigma) , the failure rate remains at 70%. Project failure not only has impact on cost but can actually result in major decline.

When changes fail, people often grow cynical impacting motivation and become afraid of their current and future security.

Analyzing reasons for failure in change and adaptation

Reasons for failure:

Methodology: Currently there is no winning formula to manage change adaptation. Organizations tend to apply latest fashion rather than what really works. Some examples

- Business process re-engineering.
- Business process modeling.
- Enterprise architecture framework.
- Six sigma.
- Business model canvas.
- System thinking.

Believing in the magic bullet; ERP, BPM etc…

- Lack of practice and effective systemic learning. Mistakes are good they assist learning process and allows.
- Lack of clear view related systemic view of goals, essential variables, historical values, events.
- Poor association of essential variables to system elements.
- Confusing innovation with transformation.
- Lack of true effective systemic data – System cockpit.
- Lack of team working, and lack of skills. Failure to associate right skills to adaptation process, failure to invest in right skill.
- Weak CEO sponsorship.
- Transformation initiative focused on wrong things (decide on golf course with consulting partner).
- Poor system governance framework.
- Inability to coordinate the right people to undertake transformation.
- Key failure related to lack of the right knowledge.
- Lack of investments to build the right knowledge.
- Lack of efficient use of knowledge.
- Misguided direction of knowledge.
- Enforcing mental constraints.

Reality in order to succeed, a systemic integrated approach is needed using a various tool-set and exploiting combined intelligence, know-how of many rather than single person or outside consulting firm.

This implies exploiting the collective intelligence within the organization with external input where needed. It is a known factor that the characteristics of the individual participants as causal factors that make up a group more intelligent, and also regular practices of a team that made it consistently more creative, especially when it had to come up with novel solutions. The importance of cognitive diversity, a characteristic that is to perceived to be a must-have for groups dealing with complex issues. It is important keep in mind that for diversity to play for (not against), certain conditions need to be fulfilled.

Leveraging the system compared to leverage function is extremely complex and difficult to realize. Organizations require a specific **protocol** that must make every effort to integrate and to network the knowledge which is available within the organization; exploit collective intelligence and cognitive diversity via a protocol that becomes an effective catalyst for knowledge generation and dissemination. This protocol raises the organizational system to a new level of communicative competence and operative efficacy and thus leads to system achieving competitive advantage relatively quickly , effective (accuracy of the what) by targeting strength and consensus.

In order to exploit collective intelligence and cognitive diversity a team **protocol** is needed to achieve major leverage. This protocol in order to exploit **team synergy** is based on the Team Syntegrity as a framework. This is a structured, non-hierarchical process for highly effective and efficient dialogue that leads to much faster, more informed outcomes and aligns people behind resulting decisions, messages and action plans that have a high chance of implementation.

Team syntegrity

[TS] Team Syntegrity is a protocol to leverage the efficacy of teamwork in solving complex problems by means of stimulating collaboration and developing cross-fertilization and creativity by exploiting **collective intelligence** and **cognitive diversity**.

Team Syntegrity is a group framework for decision-making methodology developed by Beer (1994) and offers a creative, synergetic and participative platform for studying complex problems. By providing a structured means of creating and communicating group awareness (Pérez Ríos, 2012), TS allows individuals to generate a large number of ideas in a short period, to understand connections among very different areas and themes, and to recognize the contributions and knowledge of each individual team member (Schwaninger and Leonard, 2004).

The process is designed to be non-hierarchical so that communication can be open and synergy can be captured. Its purpose is to serve as a focus for the entire process and to generate maximum variety in the resulting responses. The main goal of the application of TS methodology is to create efficient teamwork and effective outcomes by:

- **Exploit** collective **intelligence** and cognitive **diversity.**
- **Generating** a high level of **participation** among the individuals concerned.
- **Providing a structure** and a protocol **for communication** that guarantees a non-hierarchical process.

- **Allowing the team to benefit** from the **variety** and wealth of **knowledge** supplied by each individual within the group and putting into practice the **synergies** derived from the interaction among all its members;
- **Creating a collective awareness** and, if possible, a consensus regarding the central issue under consideration.

The process starts with a question concerning the issue to be studied or discussion to be dealt with within TS protocol. Its purpose is to serve as a focus for the entire process and to generate maximum variety in the resulting responses; Typical 'questions' :

- **Maximizing system** potentiality.
- **Resilience perspective** 'from what to what '.
- **Innovation initiative.**
- **Transformation initiatives.**

One of the fundamental aspect of TS is to avoid mistakes and side-effects which are more damaging as per Doerner (cf Doerner 1992) six classes mistake people are prone to make in coping with and intervening in complex systems.

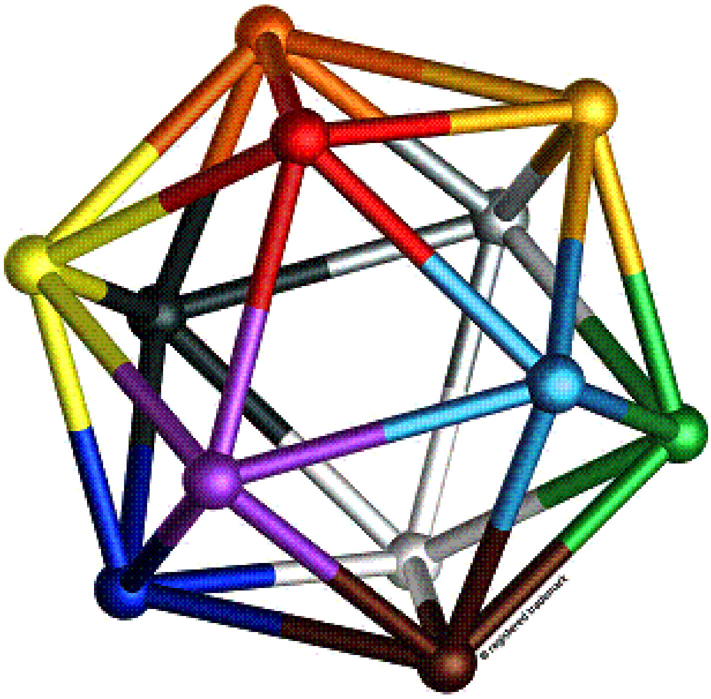
TS is based on a physical structure that is represented by geometric model ideally a icosahedron. This has 30 struts each of which represent a person. Each of the 12 edges represent a topic that is being discussed; the edges (topics) and struts (people) create internal network of interaction whereby ultimate statement of participatory democracy since each role is indistinguishable from any other without formal hierarchy (no top, bottom, sideways).

The Icosahedron geometric model is used to structure the Team Syntegrity protocol so that maximum efficacy in outcome is guaranteed. Using the Icosahedron as a model this then structures the team protocol as follows:

The formation of networks by persons which make up an **infoset** is a set of individuals who share a common concern and who are in possession of corresponding information or rather knowledge connected with the subject.

Five people manage one topic/issue, each topic represent the vertices. Each person represents an edge. **30 people (30 edges) will manage 12 topics (12 vertices).**

The 12 topics must address the broad theme / question / problem to be studied. Each topic assigned a unique colour.



Each vertex which addresses a topic/issue/problem is represented by a group of 5 people (5 edges). The edges representing each person in turn link up to other vertex. The group which is part of a vertex has specific roles:

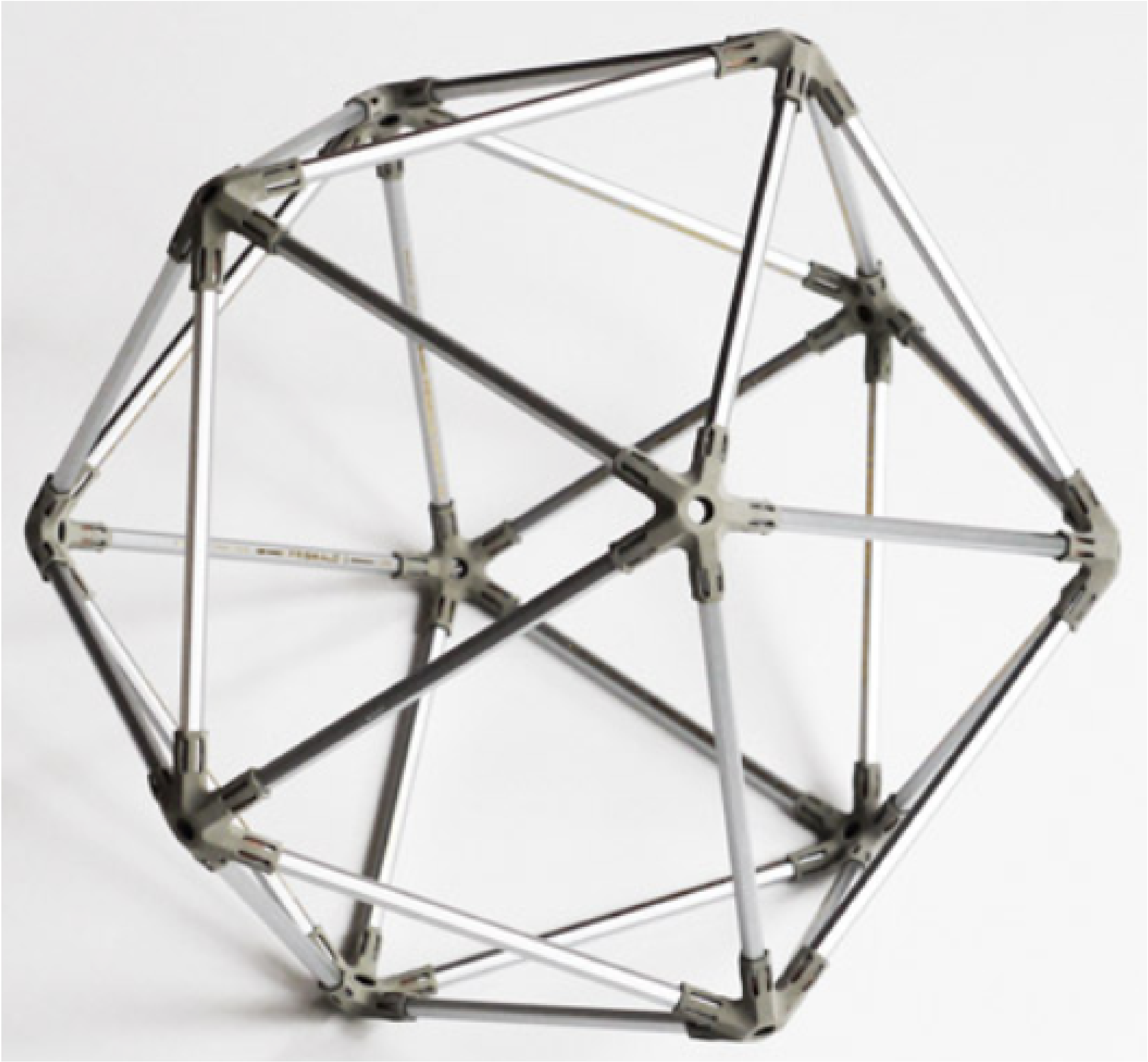
- Members are requested to identify their preference topic/issue/problem preference. Each member is then assigned to 2 vertices with the problem solving role.

Role definition; topic resolver **[TR]**. They have the task to arrive at clear action with respect to their topic.

- Each member is also assigned the role of critic in groups other than 2 assigned problem solving role. Role definition; topic critic **[TC]**. Critics are responsible for criticizing the content that is being developed by **[TR]** and for making the process a self-managed one.
- Role definition either compression or tensile.
- Each member is assigned as a critic (to provide tensile strength) of next two teams but one.
- Each member is also assigned role of observer in groups other than 2 assigned role TR or TC. Role definition; topic observer **[TO]**. **[TO] may not intervene** at all during the discussion and may only observe and gather information. They play an important role as networks of knowledge and cognitive diversity; they take on what is being discussed in the teams they observe and carry new insights, ideas, conflict and emergence into their own groups **where they are either [TR] or [TC]**. They may if necessary intervene via facilitator if there is a view that team discussion becoming problematic. The facilitator may then decide on how to approach the group if additional information is of value for further review.
- Facilitator role to ensure effective running of teams, arranging facilities, scheduling topics and members, conflict resolution, training and presenting final outcome (team outcome and all supporting documents) to sponsor TS session.

The participants **infoset** are typically selected to represent a broad group of stakeholders within the organizations and their technical capability; subject manager experts, leaders, managers, employees, partners…

The major benefit of the critic and observer role to maximize group intelligence and cognitive diversity and ensure maximum possible efficacy is realized in resolving or addressing topic/issue or problem and is exposed to the maximum amount of knowledge.



Beer applied principles of **managerial cybernetics** to work out how to achieve high levels of 'synergy' (cooperation and commitment) in groups that are large enough to satisfy issues of requisite **variety**, and small enough to accomplish something (the right thing to do; **of what to what**).

It is crucial that in order to ensure effective organizational adaptation and viability that there is harmony between two systems (**VSM** System 4 strategic management and System 3 operational management homeostat), this harmony can be achieved by adopting Team Syntegrity protocol. The key objective of Team Syntegrity is to bring together a group of people to take a comprehensive fresh view at a complex topic in order to as team to agree '**WHAT**' and "**WHY**" with respect to effective adaption (the right things to do).

The key aspect is to avoid defining the **'WHAT' and the 'WHY' that can be damaging from a system perspective**: this implies that the adaption effort causes more damage than benefit whereby emerging behavior impact viability, sustainability, potential systemic efficiency and effectiveness.

Team syntegrity protocol methodology

STEP 1: Broad Question

The protocol TS process kicks off with defining a Broad question or theme by initiated by sponsor/stakeholders/shareholders that will be addressed by the team; something that does not exists, something that needs to be transformed, new product innovation, new governance frameworks , maximizing system potentiality.

'In the context of xxx, what can be done yyyyy in order that zzzz?

Example "what is our future Y" or broad conscious design of something that does not exit, new product (innovation), new perspective, new paradigm (transformation).

TS facilitator will be responsible to facilitate the process, schedule sessions and assign members to topics that have right infoset. A spreadsheet is generated listing topics, each topic will have unique color, group members are then assigned to **each topic as TR, TC and TO**. This spreadsheet will then be used for scheduling group sessions. Topics are scheduled in some logical sequence with two topics running parallel based on agreed number of cycles. In each iteration topic overlap is changed to ensure maxim participation.

The number of cycle and duration of cycle normally agreed at start of the process. Duration each cycle could last half day with the last cycle to confirm outcome of problem resolution of each team that will then be reviewed with total group. Ideally protocol scheduled over 5 days:

- Day One; Kick off, opening question verification, expectation. Defining statements of importance, topic definition and team assignment.
- Day 2 , 3 and 4; 3 iterations of all the topics over 3 day period.
- Day 5; Final topic validation, topic summaries, final group plenary, final outcome and next steps.

Facilitators play important role with respect to observing team members, management of the topics, effective participation of team members and assist with aspects such as casual loop modeling, scenario planning. The importance team member observation is to provide sponsors the level of team member involvement and added value.

STEP 2; Topic Definition and Planning

The initial process kicks off where the participants through brainstorming are invited to present **Statements of Importance** their most creative thoughts which will be recorded on a card. These cards or Statements of Importance **[SI]** are posted on a board and examined by the participants and clustered in similar heading/category.

These individual statements are then either binned or grouped into focus topics. One SI may be assigned to more than one topic.

This forms part of free floating series of discussions called problem jostle in a large room with flip charts, boards to attach SI and other media. The SI where required are refined to ensure effective meaning and interpretation.

Participants then announce key topics that will discussion which are drawn from the **SI**. Team members have total freedom introducing topics and solicit input from others.

A consensus is then develops regarding topics that are worth further exploration and are confirmed as **Aggregated Statement of Importance [ASI]** for signature. The **ASI** contain a brief summary , category, endorsement and are associated to **SI**.

- ASI reference number.
- Theme description.
- Theme description towards broad question.
- Priority.
- Endorsement (number) participants.
- Associated SI to ASI.
- Topic colour.

Once endorsed by 5 or more participants the ASI become eligible to be considered as one the twelve topics of discussion (12 vertices of a icosahedron) .

Members are chosen based on representation of the variety of viewpoints, competence applicable to theme that will be addressed. Assignment will be as follows:

- **[TR]** Topic Representative **assigned to two topics.**
- **[TC]** Topic Critic **assigned to two topics different** to the topics assigned as **[TR].**
- **[TO]** Topic Observer **assigned to four other topics.**

The aggregated statement of importance **ASI** are sequenced by facilitators so that they can be reduced to 12 topics . A check is done to determine if certain ASI can be grouped with other ASI.

A vote is then taken by participants to formally confirm the 12 topics which then become Consolidated Statement of Importance CSI . Topics are then documented in a spreadsheet:

- Each topic represents vertices (12).
- Each topic has five struts making up the team, each strut is a member.
- Every strut is uniquely connected to two vertices; each member part of two teams (two topics).
- Summary for each member.
    - **[TR]** Assignment to team A discussing topic T1 (topic 1).
    - **[TR]** Assignment to team B discussing topic T2.
    - **[TC]** Assignment to team C discussing topic T3 as critic (tensile).
    - **[TC]** Assignment to team D discussing topic T4 as critic (tensile).
    - **[TO]** Assignment to teams discussing topic T5, T6, T7 and T8 as observers.

Once team are scheduled and are running, the critics meet with team members addressing specific topic, listen to their discussion and offer comments; constructive criticism and if required supported by casual loop diagram (cause and effect).

The critic role is designed to provide a counterweight; tension versus the compression generated by the team. This is done by constructive comments with respect to the team processes and by sharing relevant information from other teams. Further role to is to carry out planning and sequencing of topic discussions discussion in order to avoid overlaps and conflict with respect to member team association.

Each member has given a badge which is colour coded with the two teams assigned (topics compression) and two teams a critics (tensile).

The observers can only observe and cannot intervene. The purpose of observation is to gather critical knowledge that can be of great importance when managing their own topic as TR or TC. If required the TO can communicate with facilitator their concerns.

STEP 3: Outcome Resolve

Teams meet to discuss topic towards providing an initial outcome. There is at least one representative of all the other 11 team, combination of TR, TC and TO will be present in the meeting to ensure reverberation so that each thought, every idea is being transferred automatically to all other topic teams via the participants and via statements documented by team members of facilitators.

Facilitator role is to take notes (statements) during the discussion, monitor adherence to rule of the game and support the group arriving to a solution. Facilitator has an important role to guide casual loop modeling or scenario planning.

Each group meet three times during a TS session with the same group/ topic members specifically TR and TC while TO can be flexible to shift across other groups to gather other topic exposure. The three sessions allow teams to meet three times and has networked with all other teams this way maximum dissemination and **reverberations** of relevant knowledge can be realized. Team iteration approach as is follows:

First Iteration; group discusses the status quo in regard to their topic (Aggregated Statement of Importance), their associated Statements of Importance and relevance towards addressing Opening Question. TR and TC reconfirm and document any further aspect to be considered in the first Iteration Outcome Resolve (OR_1). The OR_1 is documented and printed so other teams have access and take into account for their sessions.

Second Iteration; In the second iteration team discusses ideal outcome without constraints to define ideal situation what should be done. Team Critics TC play an important role to provide inputs specifically with respect to emergence; cause and effect conditions. Team Observers **TO** purely there to observe and gather knowledge for their own team sessions. In exceptional cases TO may intervene via facilitator approval to present additional inout . Second session generates revised **Outcome Resolve** (OR_2) documented and made available to other team. Additional documentation such as scenario modeling, technical papers, Causal Loop modeling are attached. This is fundamental to provide credence to outcome resolve.

Third Iteration; In this interaction there is the final focus towards the ideal '**what should be done**' within this topic that will provide maximum leverage with respect to Opening question / Problem / Issue . The proposal for implementation to the key sponsors should be realizable with initial estimation with respect to complexity, effort and possibility of risk and possible damage should not be implemented adequately/correctly. This is the documented in final Outcome Resolve for Implementation (OR_I) The OR_I should also include executive summary to be included in overall executive summary of all the groups addressed to project sponsor.

A fourth iteration may be possible if needed based on request from TR and TC to refine and change content of their OR due to unexpected emergence.

In all interactions the critic role becomes fundamental to consider possible side-effects and ensure a feasible optimum outcome.

The teams Outcome Resolve are achieved through a synergy and integration by:

- **The Outcome Resolve** are developed to provide a detailed action plan that integrates the best knowledge of all the participants by exploiting collective d intelligence and cognitive diversity.
- The team members share strong commitment for implementation of what is jointly developed.
- The participants via the structure of iteration and team structures are highly networked and leverages team building.
- Participants learn from each other and better understand the other participant's positions, constraints and emergence. This enables leveraging the whole rather than the parts.

STEP 4: Final Outcome

The team session closes with a group plenary organized by facilitator. This plenary session has the following purpose:

- It reconfirms the question under study raised by sponsors and the purpose.
- Facilitator confirms topics that were agreed.
- For each topic an executive summary is presented by individual group representative.
- The facilitator the provides a list of Final Statement of Importance (FSI) for realization with a specific leverage ranking , risk factor and implementation complexity and effort.
- The FSI also define possible systemic conflict/constraint that requires resolution.
- If required it facilitator may suggest spin-off Team Syntegrity session for specific question/ issues to be resolved based on outcome of the different groups.
- The facilitator them provides sponsors the following output:
  - Documented executive summary with attached final outcome resolve (associated TR and TC) from the groups.
  - All the Outcome Resolve iteration.
  - List of members roles, association to teams.
  - All supporting documentation such statement of importance, simulation documents , scenario planning, causal loop modeling.
  - A possible high level implementation plan for sponsors which relate to the WHAT and WHY, WHERE, WHEN with respect to main question.

Models to realization

Introduction

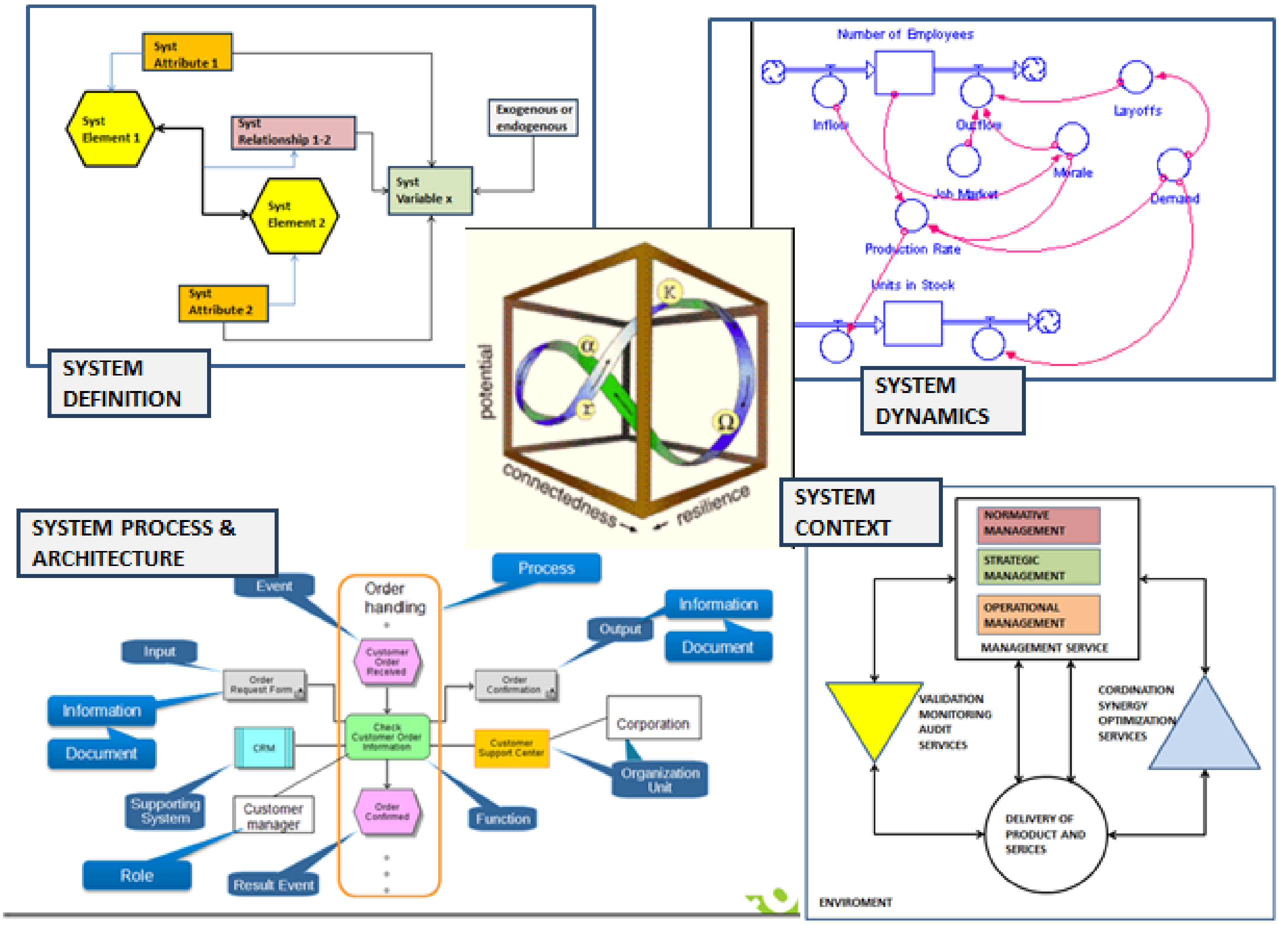
> **“The behavior of a system cannot be known just by knowing the elements of which the system is made.”**

For for effective system governance, steering, adaptation and transformation initiatives to be successful it is important to define and understand current system baseline and behavior (actuality). This is fundamental to apply effective leverage and change, minimize damage, cost and risks by applying the right kind of intervention. System analysis implies:

- **System Purpose**, **System Structure** (elements and behaviour, variables).
- **System Content**: System Behavior, System Dynamics.
- **System Governance**: Viability, Complexity, Constraints and Cohesion.
- **System Support Processes.**
- **Enterprise IT Architecture.**

The definition of systemic baselines then enables a process of undertaking effective adaptation initiatives to improve system efficiency, **capability, potentiality, potential, viability** and **resilience**.

Effective **adaptability** entails defining the rights things to do considering system state and environmental conditions.

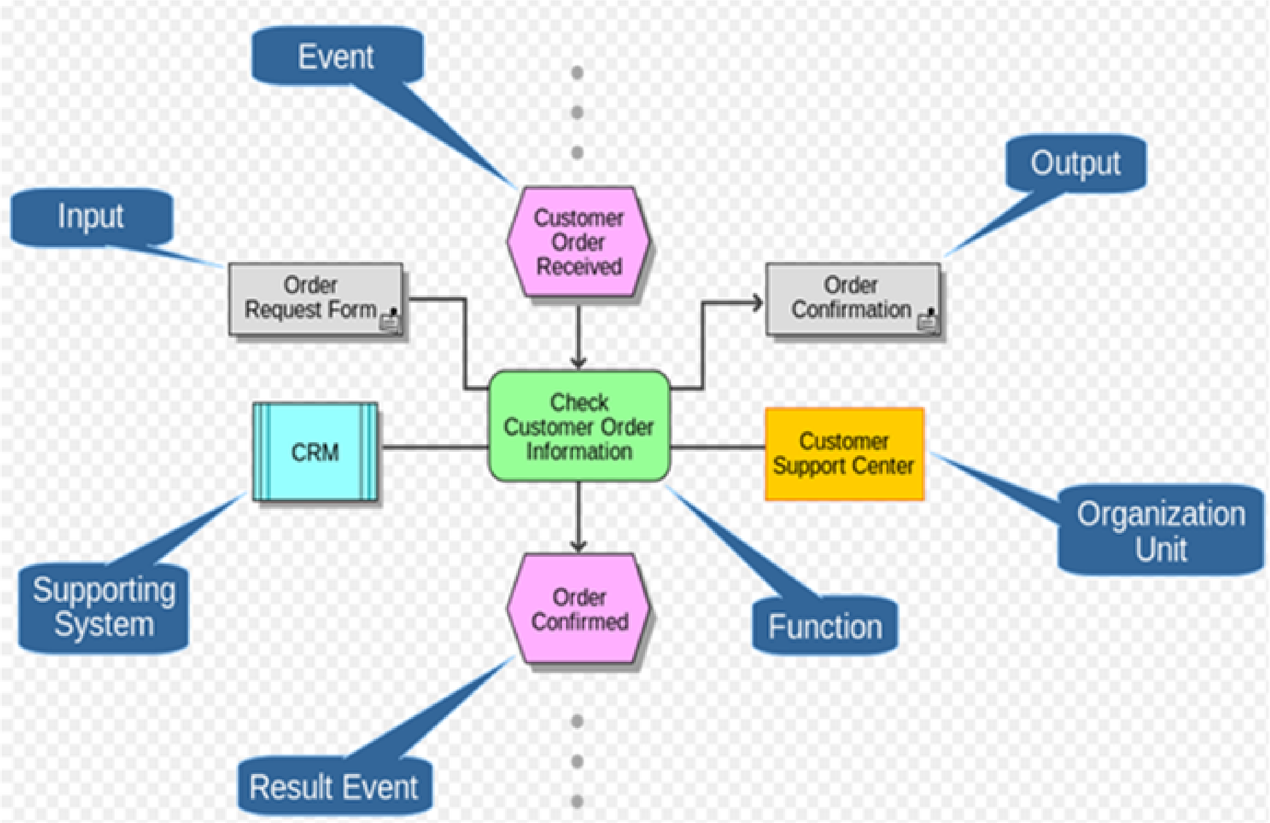


Effective adaptability entails defining the rights things to do considering system state and environmental conditions.

Process management

Business process management (BPM) is a systematic approach to making an organization’s workflow more effective, more efficient and more capable of adapting to an ever-changing environment. A business process is an activity or set of activities that will accomplish a specific organizational goal. The goal of BPM is to reduce human error and miscommunication and focus stakeholders on the requirements of their roles. BPM is a subset of infrastructure management, an administrative area concerned with maintaining and optimizing an organization’s equipment and core operations. A business process is an activity or set of activities that will accomplish a specific organizational goal.

From a system perspective the processes must realize the system purpose and sub-system functions in order to achieve its stated objective. The processes need to operate within the governance model in order to maintain system ‘set-course’.



Event

Events are passive elements in event-driven process chains (EPC). They describe under what circumstances a function or a process works or which state a function or a process results in. Examples of events are “requirement captured”, “material in stock”, etc. In the EPC graph an event is represented as hexagon. In general, an EPC diagram must start with an event and end with an event.

Function

Functions are active elements in an EPC. They model the tasks or activities within the company. Functions describe transformations from an initial state to a resulting state. If different resulting states can occur, the selection of the respective resulting state can be modeled explicitly as a decision function using logical connectors. Functions can be refined into another EPC. In this case it is called a hierarchical function. Examples of functions are “capture requirement”, “check material in stock”, etc... In the event-driven process chain graph a function is represented as rounded rectangle.

Process owner

Process owner is responsible for a function (i.e. a booking clerk is responsible for booking journeys). The process owner is usually part of an organization unit (i.e. a booking clerk belongs to the booking department). It is represented as a square with a vertical line.

Organization unit

Organization units determine which organization within the structure of an enterprise is responsible for a specific function. Examples are "sales department", "procurement department", etc. It is represented as an ellipse with a vertical line.

Information, material, or resource object

In the event-driven process chain, the information, material, or resource objects portray objects in the real world, for example business objects, entities, etc..., which can be input data serving as the basis for a function, or output data produced by a function. Examples are "material", "order", etc. In the EPC graph such an object is represented as rectangle.

Information technology from a systemic perspective

A system consists of interconnected set of elements (sub-systems) that are coherently organized and work in coordination with each other to achieve a desired goal or overall objectives of the whole. These elements derive their strength by means of association and influence with other elements whereby collective contribution of the system is greater aggregate individual elements: this is known as systemic synergy. Cybernetics recognizes that a **'whole' system exhibits emergent properties that are not found in its parts.**

A system when examined, is the **product** of the **interactions** of four main aspects:

- the **number of elements.**
- their **interactions.**
- their **attributes.**
- and their degree of **organization**.

The number of elements refers to the number of **sub-system** responsible for transformation (input, transformation, and output) contained within a system. The interaction describes the richness of the connectivity between these elements. Attributes refers to **individual properties** of the elements that is their particular nature and features. The degree of organization is the extent to which interactions and attributes are guided by predetermined rules.

From a system perspective; complexity is the **product of richness** in the connections between components of a system.

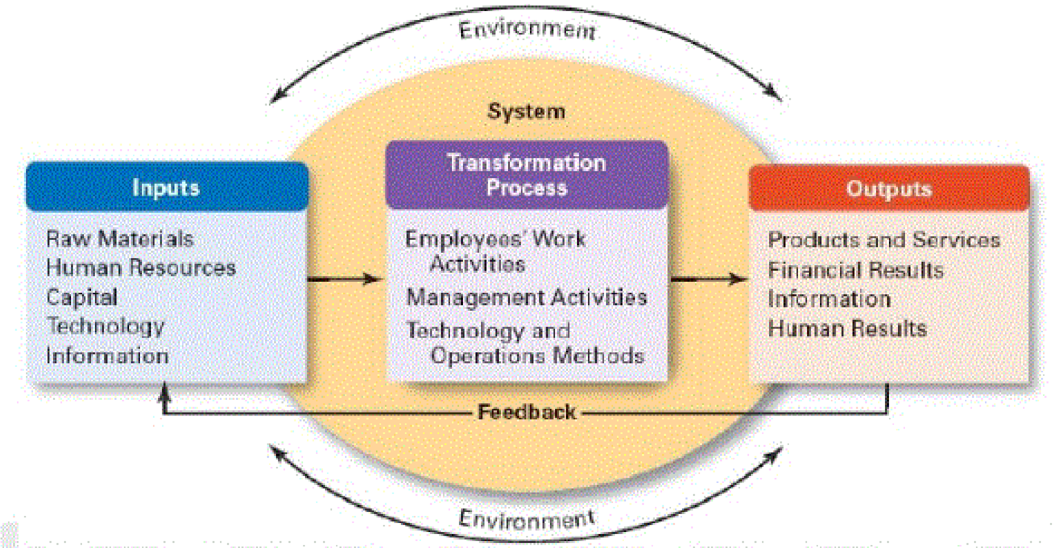
Understanding **complexity** implies understanding the system; when examined complexity considers interactions of four main aspects: the **number of elements**, their **interactions**, their **attributes** and their degree of **organization**. The number of elements refers to the number of **sub-system** responsible for transformation (input, transformation, and output) contained in system. The interaction describes the richness of the connectivity between these elements. Attributes refers to **individual properties** of the elements that is their particular nature and features. The degree of organization is the extent to which interactions and attributes are guided by predetermined rules.

Self-regulation describes the ability of a system **to 'manage' itself** (**feedback**) towards its purpose or goals despite environmental disturbances based on ether balancing or reinforcing feedback:

- First order feedback whereby the goal is **determined externally** to it.
- Second order feedback where system is capable of choosing between **variety responses** to environmental changes in order to achieve its goal.
- Third order system is one that is capable of **changing the goal state itself** in response to feedback process determining the goal internally s opposed to externally.

System behavior can either by deterministic where its behavior can be known in advance as any input to the system will generate predictable outcome. Probabilism exists where there are elements of the system whole behavior is at least **partially random**: where 'most likely' outcome of the predicted variables are uncertain. **(Variety engineering**).

> "System effectiveness and efficiency are attained through interaction of the sub-systems in pursuit of the purpose of the system in its environment via sub-systems."



Being effective is about doing the right things, **while being efficient** is about doing things right are both fundamental in achieving goals related to system potential, potentiality and capability. This is only possible if there is total cohesion by all the sub-systems with respect pursuit of system purpose.

Within a system there is sub-system; Information Technology Infrastructure which acts as mechanism supporting each element responsible for realizing system oI’vebjective. From a system perspective IT has a fundamental role in that:

- It impacts the function of the sub-system elements responsible for transformation.
- It impacts the relationship between sub-systems.
- It impacts attributes and properties of the sub-system.
- It should measure variables of attributes and their goal state.
- It impacts efficacy with respect to synchronization of the various system elements achieving its goals.
- It provides fundamental information for decision making (governance).

Based on the role of Information Technology, it is then fundamental that it does not impose constraints, that is adaptive due to the fact that relationship between system elements and their properties are adaptive due to changing environmental conditions and that it enables efficiency by maximizing potentiality.

From a system perspective **Information Technology Infrastructure** (ITI) consists of combined set of hardware, software, networks, facilities, etc. (including all of the information technology store, retrieve, transmit, and manipulate data), in order to support the various sub-system ability to realize system purpose by managing its platform, processes, devices and data.

IT management is the discipline whereby all of the information technology resources of a system are managed in accordance with its needs and priorities. These resources may include tangible investments like computer hardware, software, data, networks and data center facilities, as well as the staff who are hired to maintain them.

Enterprise Architecture is a discipline for pro-actively and holistically leading enterprise responses to disruptive forces by identifying and analyzing the execution of change toward desired business vision and outcomes. EA delivers value by presenting business and IT leaders with signature-ready recommendations for adjusting policies and projects to achieve target business outcomes that capitalize on relevant business disruptions.

THE WHOLE

From a Systemic perspective ITI needs to be in total cohesion with the overall purpose and overall goals/objectives of the whole (system):

The Information Technology Infrastructure must support the various system functions in achieving its purpose and must ensure cohesion towards total system purpose and goals.

- The ITI sub-system must be an enabler for effective viability management.
- The ITI sub-systems must be enabler for leveraging optimum potentiality and capability.
- The ITI sub-systems must contain effective feedback in order to optimize system. processes
- The ITI sub-systems must be an abler the effective co-ordination and synchronization the sub-systems responsible for the primary transformation activities (delivery products / services) The ITI must be able elevate conflict with respect to co-ordination various function due to constraints.
- The ITI sub-systems must be able to generate alerts timeously with respect to deviations from stated goals of critical variables goal sate.
- The ITI sub-systems must be adaptive: must be adaptable to changing business requirements.
- The ITI sub-systems must responsive : must be able to respond to business needs timeously.
- The ITI sub-systems must be flexible (rather than rigid) : must be flexible to changing system needs.
- The ITI sub-system must be efficient (cost and resource perspective).

In summary the ITI sub-system must be managed so that it's effective: therefore the right IT infrastructure that that is effective, adaptive, responsive and efficient.

Further reading

- Norbert Wiener – The human use of human beings: Cybernetics and Society
- Norbert Wiener – Control and communication in the animal and the machine.
- W. Ross Ashby – An introduction to cybernetics
- W. Ross Ashby – Design for a brain: The origins of adaptive behavior
- V. V. Purin & R. M. Buyevskiy – Introduction to medical cybernetic
- Stafford Beer – Brain of the firm: Managerial cybernetics of organization
- Stafford Beer – Beyond Dispute: The Invention of Team Syntegrity
- Stafford Beer – Designing freedom
- Andrew Pickering – The cybernetic brain
- Maxwell Maltz – The new psycho-cybernetics
- Donella H. Meadows – Thinking in systems
- Sam Carpenter – The system mindset
- Sam Carpenter – Work the system

Acknowledgement

Recent works permitting to harness to power of this wonderful science is given to mankind by:

- Cybernetics
  - Affolter Matias
  - Javier Livas Cantu
- systems.hitchins.net
  - D K Hitchins
- thesystemsmindset.com
  - Sam Carpenter
- criticalthinking.org
  - Dr. Linda Elder
  - Dr. Richard Paul
- systemic2016.wordpress.com
- Cybernetics's founding fathers...